Ballast Water Management System

Application for AMS determination and US Type Approval

GENERAL DISCLAIMER

Model	Treatment rated capacity (m^3/hr)
AquaStar™ BWMS H-200	200
AquaStar™ BWMS H-200S/H-200S-Ex[1]	350
AquaStar™ BWMS H-250	500
AquaStar™ BWMS H-300/H-300-Ex	800
AquaStar™ BWMS H-350/H-350-Ex	1,100
AquaStar™ BWMS H-450	1,800
AquaStar™ BWMS H-550	2,600
AquaStar™ BWMS H-650/H-650-Ex	3,000
AquaStar™ BWMS H-700	4,000
AquaStar™ BWMS H-750	5,000

[1] Explosion-proof type

14 Models = 10 Standard models + 4 Explosion-proof models

Type Approval Certificate of BWMS from Republic of Korea

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ABBREVIATION LIST

ABBREVIATION		FULL NAME
A	AAV	Auto Air Vent
	AB	Air Blower
	AC	Alternating Current
	AMS	Alternate Management System
	AS	Active Substances
	ASS	Air Supply System
	AV	Air Ventury
B	BP	Ballast Pump
	BR	Bus Rod
	BT	Ballast Tank
	BWMS	Ballast Water Management System
C	CL2D	Chlorine gas Detector
	CM	Conductivity Meter
	COC	Cargo Oil Control (=Deck office)
	CRO	Combined Residual Oxidants
	CSU	Control System Unit
D	DC	Direct Current
	DPD	N,N-Diethyl-P-Phenylenediamine
E	EL	Electrolyzer Unit
	Ex	Explosion-proof type
F	FRO	Free Residual Oxidants
	FS	Flow Switch
	FWSS	Fresh Water Supply System
G	GS	Gas Separator Unit
H	H2D	Hydrogen gas Detector
I	IGBT	Insulated Gate Bipolar Transistor
	IMO	International Maritime Organization
L	LCP	Local Control Panel
	LEL	Lower Explosion Limit
	LG	Level Gauge

	LT	Level Transmitter
M	**MCP**	Master Control Panel
	MFM	Main Flow Meter
	MLTM	Ministry of Land, Transport and Maritime Affairs
	MSBD	Main Switch Board
N	**NAP**	Neutralizing Agent Pump
	NCP	Neutralizer Control Panel
	NIP	Neutralization Injection Port Unit
	NSPP	Neutralization Sampling Port Unit
	NTP	Neutralizing Transfer Pump
	NT	Neutralizing agent storage tank
	NU	Neutralization Unit
P	**PID**	Proportional/Integral/Differential
	P&ID	Piping and Instrument Diagram
	PI	Pressure Indicator
	PFD	Process Flow Diagram
	PLC	Programmable Logic Control
	PSU	Practical Salinity Unit
	PT	Pressure Transmitter
	PTS	Pressure Transmitter Set
	PWD	Power Distributor
R	**RCP**	Rectifier Control Panel
S	**SCR**	Silicon Controlled Rectifier
	SIP	Sampling with Injection Port Unit
	SP	Smart Pipe Unit
	SPP	Sampling Port Unit
T	**TBS**	Thermal Bimetal Switch
	TRO	Total Residual Oxidants
		TRO_1: ballasting/TRO_2: in-tank/TRO_3: de-ballasting
	TT	Temperature Transmitter
U	**USCG**	United States Coast Guard

Contents

1. Information

The transportation of ballast water on the oceans amounts to 10 billion tons per year, and aquatic organisms more than 7,000 individuals are unavoidably transported. Non-indigenous aquatic species of animals, plants, and bacteria have been introduced into new environments through discharge of ballast water with severe impact on native ecosystems. In 2004, IMO adopted "the International Convention for the Control and Management of Ship's Ballast Water and Sediments" and prepared a quality standard for discharge of ballast water. In 2009, USCG published a notice of proposed rulemaking entitled "Standards for Living Organisms in Ship's Ballast Water Discharged in US Waters" in the Federal Register.

Ballast water treatment technologies (filtration, ultraviolet, ozone and electrolysis etc.) had developed and are developing all over the world until now.

AquaStar™ BWMS developed by AQUA Eng. Co., Ltd. (website: www.aquaeng.kr) is the electrolytic system. In AquaStar™ BWMS, TRO (including AS) is produced in-situ by electrolyzing the natural seawater and brackish water. AquaStar™ BWMS is composed of SP, EL, NU and CSU. The design of these components is very simple, and these components would be easy to directly install the main ballast pipe line. AquaStar™ BWMS that is directly set up a ballast line of a ship is working more efficiently and economically than general disinfection equipment. The aim of AquaStar™ BWMS is that harmful aquatic organisms in the ballast water are simply treated.

2. System Description

2.1. General

Specification of AquaStar™ BWMS

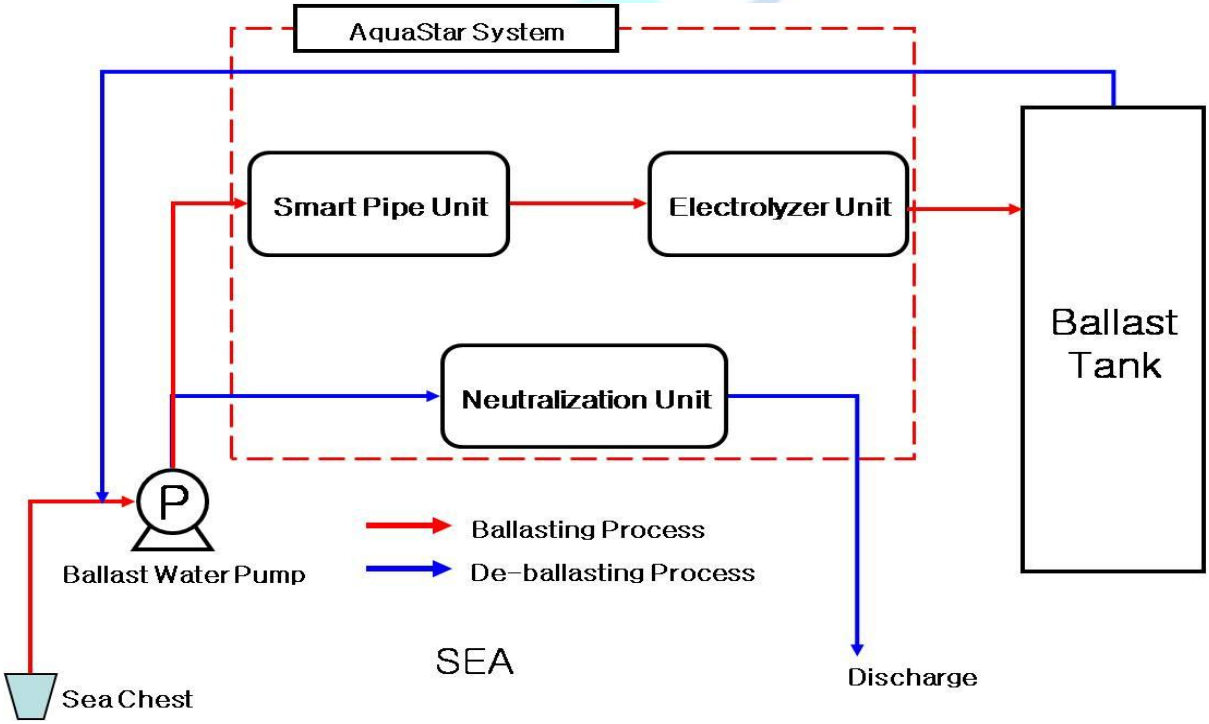
Division	Specification	Remark
Model	H-200 ~ H-750	
Flow rate	200 ~ 5,000 m^3/h	
Electrolyzer system unit		
Power consumption TRO concentration Operation performance	12 ~ 400 kW (10 mg/L as Cl_2) 8 ~ 10 mg/L as Cl_2 Less than 10 mg/L as Cl_2	
Neutralization system unit		
Neutralizing performance Neutralizing agent	Less than 0.2 mg/L as Cl_2 Sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$)	
CSU		
Control method Installation location Display	Dual control system / Automatic operation MCP (COC) / LCP (Engine room) LCD, Touch screen, Graphical user interface	
Others		
Allowable operating salinity Designed pressure	More than 10 PSU 5 kg/cm^2 (Test pressure: Max. 7.5 kg/cm^2)	

2.1.1. System boundary

Main components of AquaStar™ BWMS are composed of SP, EL, NU and CSU.
SP and EL installed in ballasting process line is used to disinfect.
NU installed in de-ballasting process line is used to discharge treated water similar to TRO concentration of the natural seawater.
CSU is possible to automatically or manually control and store or monitor the operation data of AquaStar™ BWMS. The overall diagram of AquaStar™ BWMS is shown in a below figure.

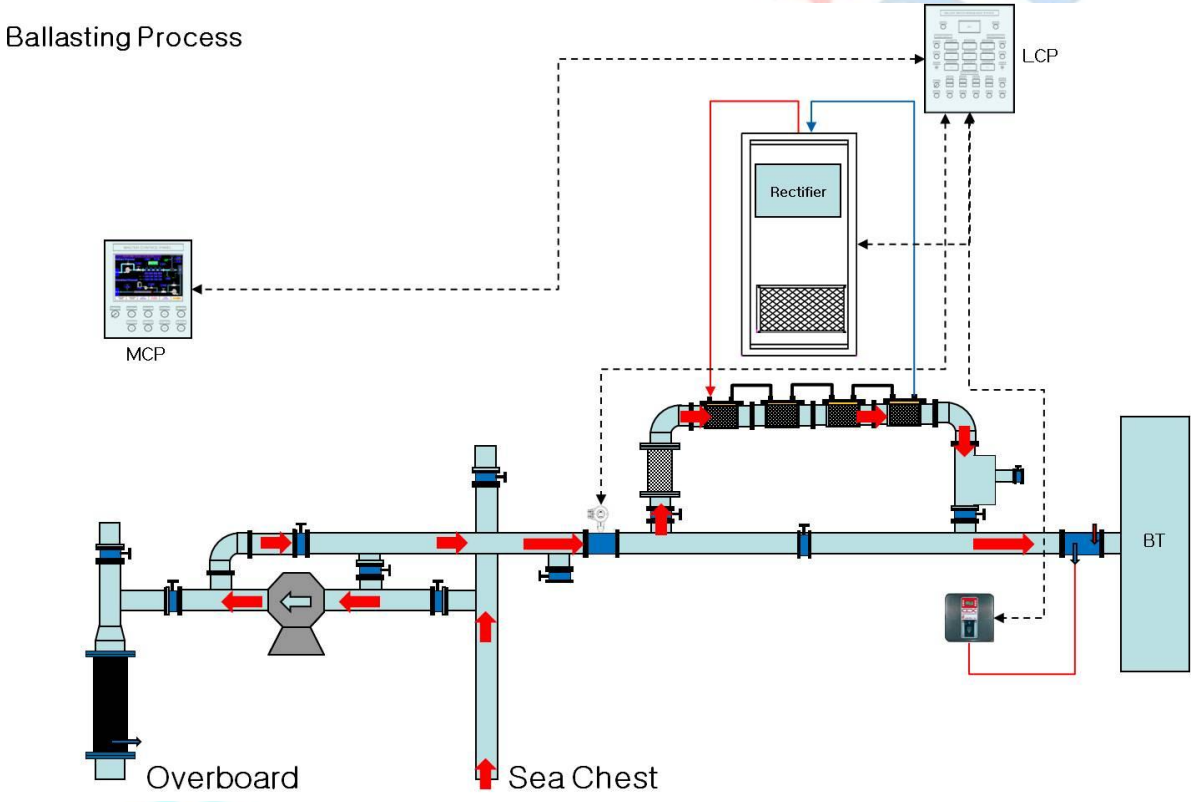
During ballasting, equipment operated in AquaStar™ BWMS
: SP and EL

During de-ballasting, equipment operated in AquaStar™ BWMS
: NU



2.1.1.1. Ballasting process

Ballasting process of AquaStar™ BWMS is measured TRO value generated by EL. If the initial target TRO value set at CSU differs in a measured TRO value, the current of rectifier by CSU is controlled to maintain the target TRO value.
During ballasting process, in the first step, SP is removing and weakening most aquatic organisms larger than 50 μm in the ballast water and is increasing the disinfectant efficiency of electrolysis. In the second step, harmful aquatic organisms are disinfected by TRO generated EL with seawater or brackish water.



2.1.1.2. De-ballasting process

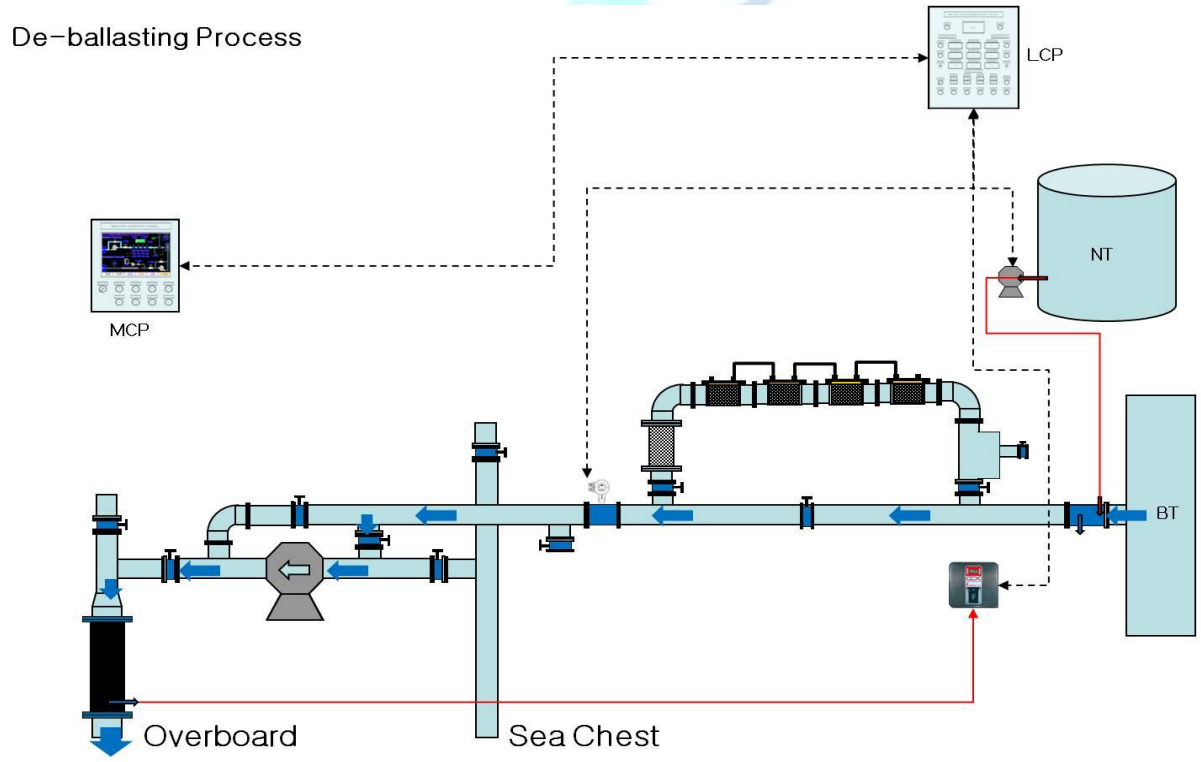
De-ballasting process of AquaStar™ BWMS is as follows;

Before de-ballasting the treated water in BT,

1) TRO value of treated water is measured by TRO sensor.
2) The measured value of TRO is transferred to CSU.
3) Numerical calculation related to neutralization is conducted by PLC stored at CSU.
4) Then, CSU determines the suitable flow rate of NAP.

※ In case of no measured TRO concentration of treated water in BT before de-ballasting, the default value of TRO concentration supplied AQUA Eng. Co., Ltd. should be used.

During de-ballasting process, Neutralization system unit of AquaStar™ BWMS is removed TRO of treated water, and then treated water similar to TRO of natural seawater is discharging (< 0.2 mg/L as Cl_2).



2.1.2. Principle of the system

2.1.2.1. Principle of electrolysis in seawater

AS act to disinfect viable organisms in ballast water. In AquaStar™ BWMS, AS are produced in-situ by electrolysis of natural seawater. During electrolysis of seawater, NaOCl is formed by the reaction with Cl_2 produced at the anode and NaOH produced at the cathode. Also, a part of Cl_2 dissolves immediately into H_2O to produce HOCl/OCl^- which exists in equilibrium in the seawater. And some portion of HOCl reacts with bromine ion in seawater and generates HOBr/OBr^- in equilibrium in the seawater. These compounds are FRO. Chloramines and bromamines are also produced by the electrolytic process and are here referred to as CRO. FRO and CRO together are referred to as TRO. All TRO compounds may have disinfectant effects; hence they are here regarded as AS.

During electrolysis of seawater, NaOCl is formed by the reaction to Cl_2 produced at the anode and NaOH produced at the cathode (reaction 5). Also, Cl_2 reacts immediately with H_2O to produce HOCl (reactions 6).
At the anode, both H_2O and Cl^- are oxidized to produce O_2 (reaction 1) and Cl_2 (reaction 2), respectively.

(reaction 1) $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

(reaction 2) $2Cl^- \rightarrow Cl_2 + 2e^-$

At the cathode, NaOH and H_2 are formed according to reaction 3.

(reaction 3) $2H_2O + 2Na^+ + 2e^- \rightarrow 2NaOH + H_2$

The overall reaction of the seawater electrolysis is described in the reaction 4.

(reaction 4) $2NaCl\ (2Na^+ + 2Cl^-) + 2H_2O \rightarrow 2Na^+ + 2OH^- + Cl_2 + H_2$

NaOCl is formed by the reaction to Cl_2 produced at the anode and NaOH produced at the cathode (reaction 5).

(reaction 5) $Cl_2 + NaOH \rightarrow NaOCl + H^+ + Cl^-$

Simultaneously with reaction 5, Cl_2 formed at the anode reacts immediately with H_2O to form HOCl according to reaction 6.

(reaction 6) $Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$

HOCl dissociates to OCl^- and H^+ in the bulk solution reaction 7; dissociation depends on several factors, mainly pH.

(reaction 7) $HOCl \leftrightarrow OCl^- + H^+$

The disinfecting effect of hypochlorous acid and hypochlorite is due to the release of atomic oxygen which is highly reactive, according to reaction 8 and 9, respectively.

(reaction 8) $HOCl \rightarrow O + Cl^- + H^+$

(reaction 9) $OCl^- \rightarrow O + Cl^-$

Natural seawater contains approximately 60 ~ 70 mg/L of Br, existing as Br^-. Under alkaline conditions, Br^- also is oxidized by HOCl to HOBr according to the following reaction 10.

(reaction 10) $HOCl + Br^- \rightarrow HOBr + Cl^-$

HOBr dissociates in water in a similar reaction to HOCl (reaction 11), and also acts as an effective disinfectant.

(reaction 11) $HOBr \leftrightarrow OBr^- + H^+$

2.1.2.2. Principle of neutralization

During de-ballasting, the treated water is neutralized to keep below 0.2 mg/L as Cl_2 without any risk to the marine environment. The neutralizing agent is sodium thiosulfate ($Na_2S_2O_3$).
The neutralizing reactions of $Na_2S_2O_3$ and NaOCl are described in reactions 1 and 2.

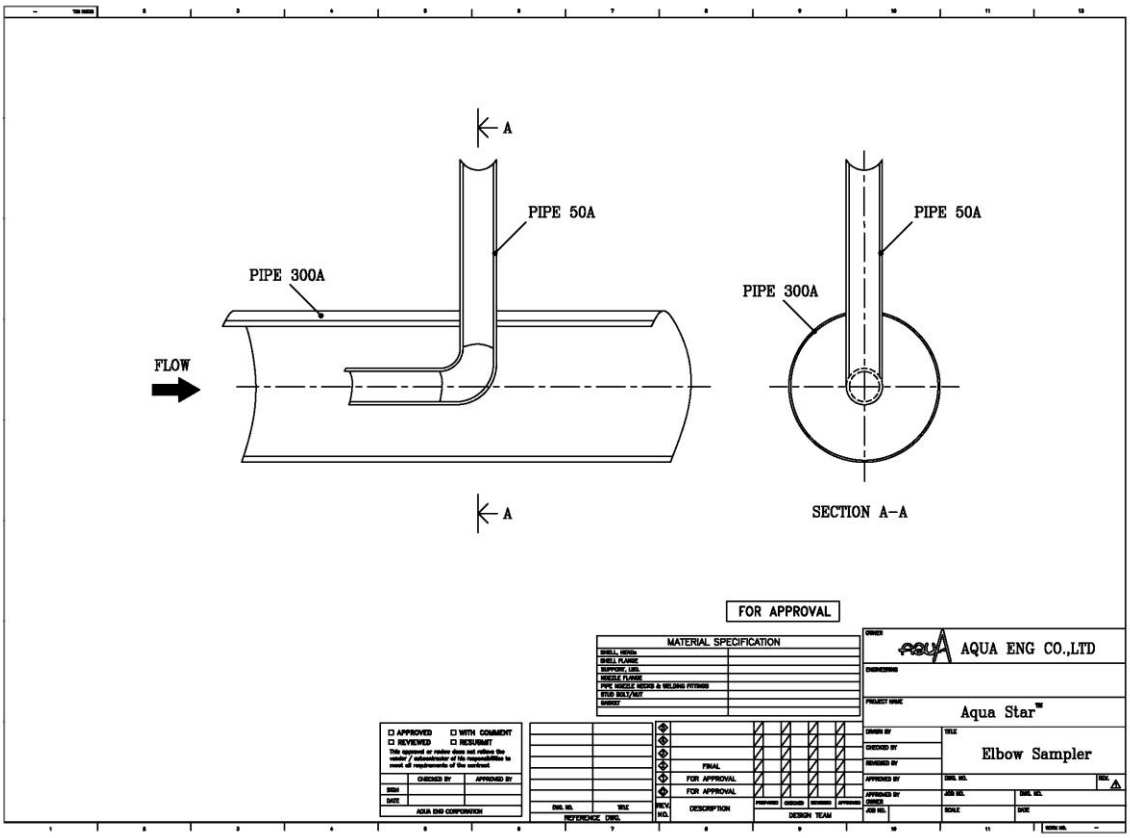
(reaction 1) $Na_2S_2O_3 + 3NaOCl \rightarrow 3NaCl + Na_2S_2O_6$
(reaction 2) $Na_2S_2O_3 + 4NaOCl + 2NaOH \rightarrow 4NaCl + 2Na_2SO_4 + H_2O$

The neutralizing reactions of $Na_2S_2O_3$ and HOCl/HOBr are described in reactions 3 and 4.

(reaction 3) $Na_2S_2O_3 + 4OCl^- + H_2O \rightarrow 2NaCl + 2SO_4^{2-} + 2HCl$
(reaction 4) $Na_2S_2O_3 + 4OBr^- + H_2O \rightarrow 2NaCl + 2SO_4^{2-} + 2HBr$

2.1.3. Sampling facility

According to the paper of "Analysis of Ballast water sampling port designs using Computational Fluid Dynamics (See the Appendix D-4)", in order to gain representative samples from the sampling ports, the sampling port is installed in the center of pipe and in the opposite direction of the water flow, and is used to sampling of the efficacious, chemical and toxicity test.



< Drawing of sampling port using AquaStar™ BWMS >

2.2. Control system

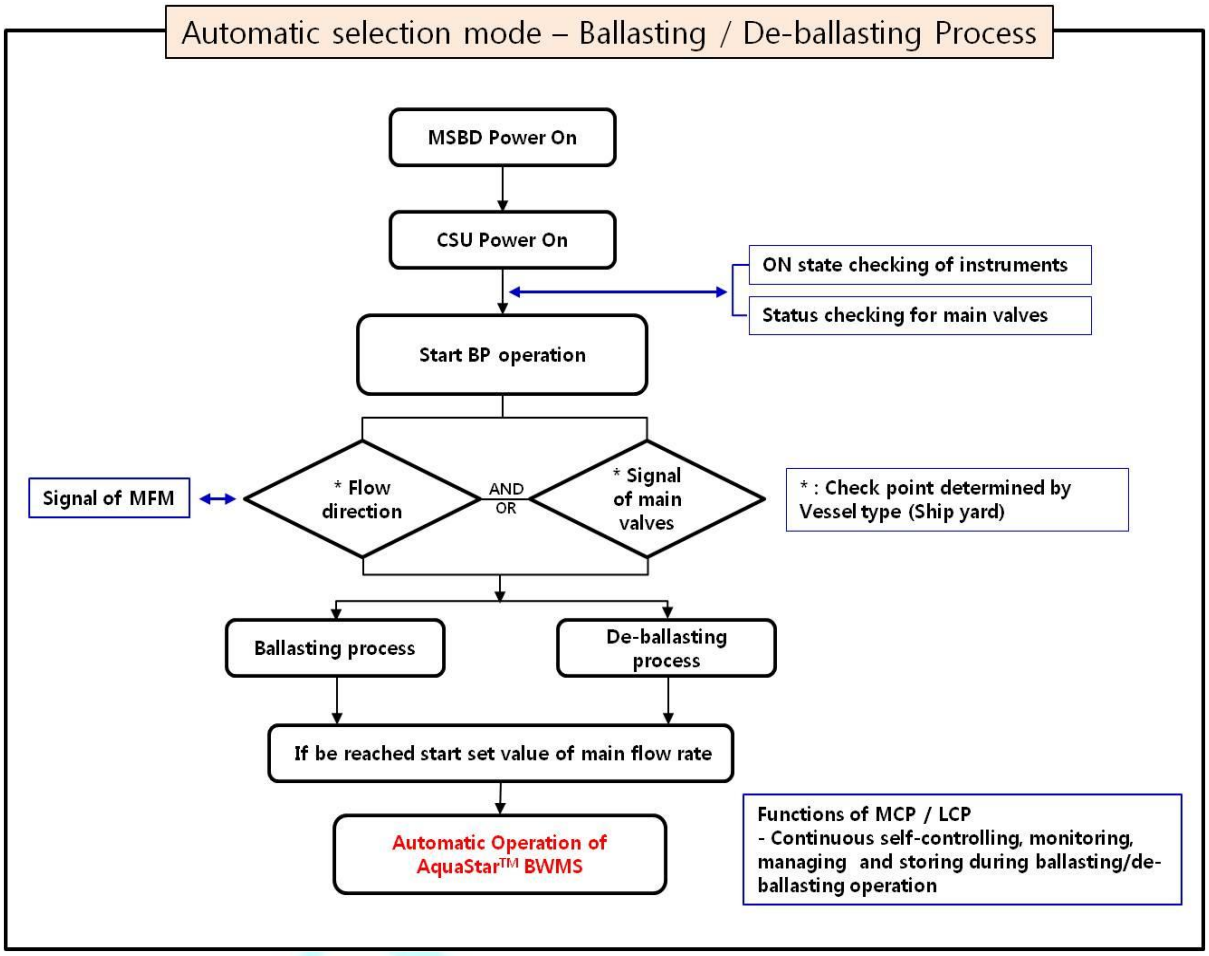
During ballasting and de-ballasting, CSU automatically monitors and controls the operation of AquaStar™ BWMS. CSU of AquaStar™ BWMS is based on PLC and is designed as available equipment at ship.

Functions of CSU are as follows;

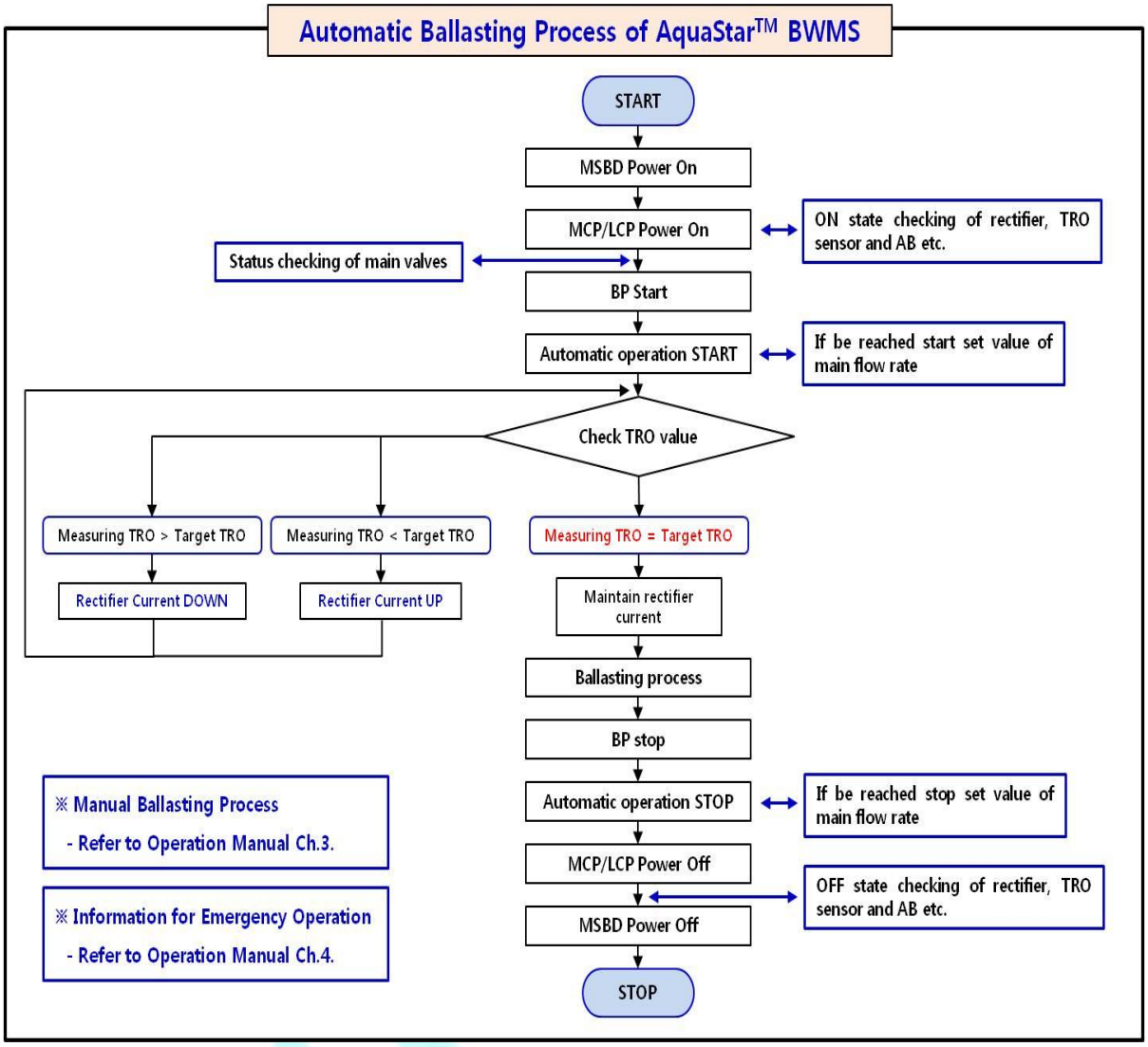
- Automatic and manual operation of AquaStar™ BWMS is possible during ballasting and de-ballasting (to adjust necessary treatment dosage for ballasting/de-ballasting mode).
- During the operation of AquaStar™ BWMS, when an unexpected problem occurs, alarm system operates, and then AquaStar™ BWMS should be shut down.
- Various operation data and instruments (equipment) can be stored and displayed.
- Alarm of operation for cleaning, calibration or repair can be stored and displayed.
- The status for emergency and by-pass operation can be stored and displayed.
- CSU can show whether all instruments of AquaStar™ BWMS are normally functioning or failure of the BWMS.
- CSU stores data on monitored functions and conditions for at 24 months and the operation data can be displayed or printed for inspection.

2.2.1. Control flow chart of system

2.2.1.1. Automatic selection mode for ballasting and de-ballasting operation



2.2.1.2. Automatic ballasting process of AquaStar™ BWMS



Numerical calculation of ballasting process;

$$\textbf{Current of rectifier} = P1 \times P2 \times P3 \times F1 \times T_{TRO1} / P_{ele}$$

F1 = Main flow rate of BP (m^3/hr)

T_{TRO1} = Target TRO value at ballasting process (Setting value)

TRO1 = Measuring TRO value of TRO sensor during ballasting process

P1 = Parameter (Theoretical value)

P2 = Experimental efficiency (Setting value)

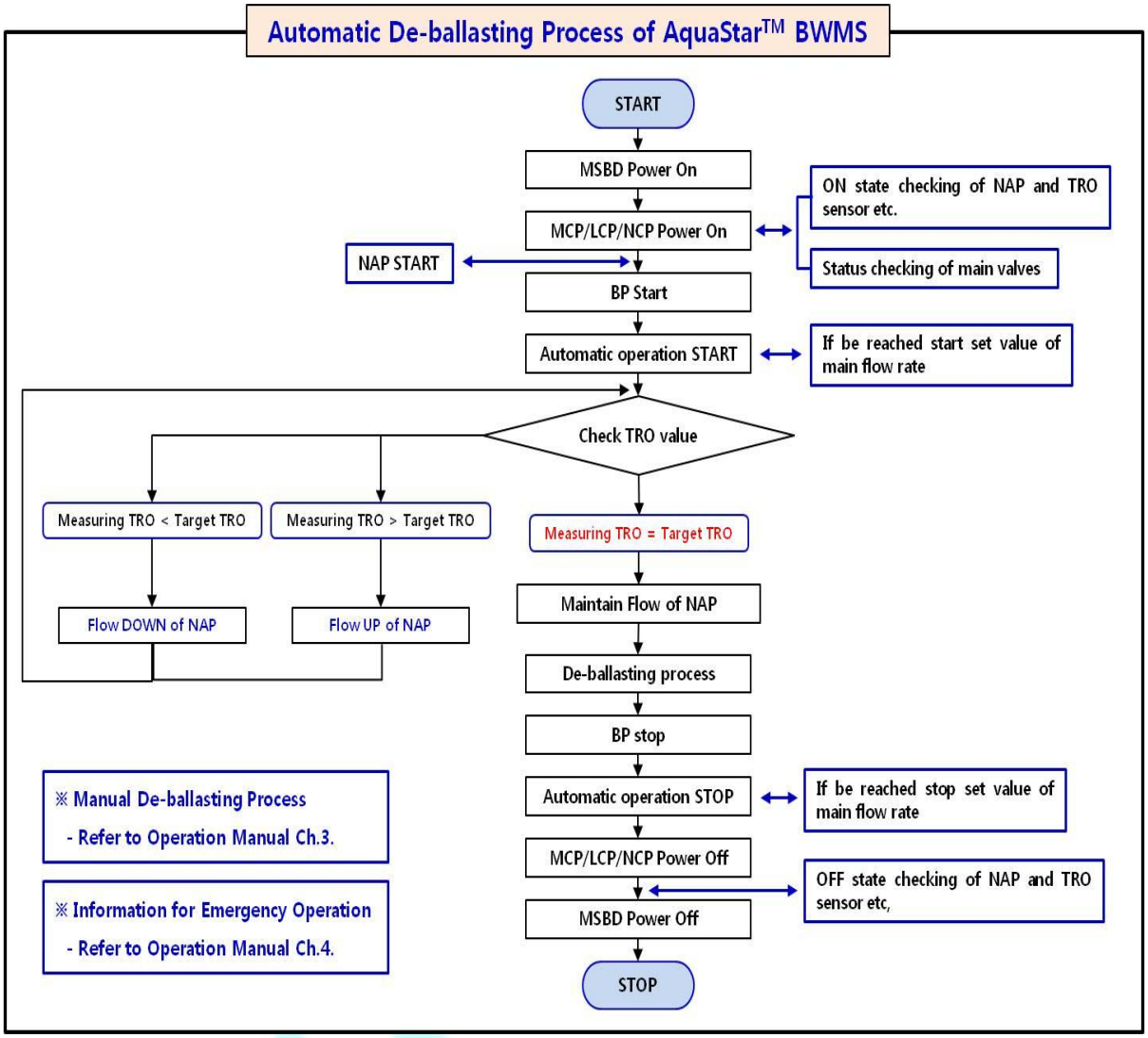
P_{ele} = factor, connecting EL (Default=4)

P3 = Estimated between measuring TRO1 and Target TRO
Control variable in program (Default=1)

If (T_{TRO1} – TRO1) > 0 or positive (+) ⇒ Current increase (Calculating with TRO1 and T_{TRO1} value)

If (T_{TRO1} – TRO1) < 0 or negative (-) ⇒ Current decrease (Calculating with TRO1 and T_{TRO1} value)

2.2.1.3. Automatic de-ballasting process of AquaStar™ BWMS



Numerical calculation of de-ballasting process;

$$\textbf{Flow rate of NAP (L/hr)} = N1 \times N2 \times N3 \times F2 \times (TRO2 - T_{TRO3}) / C1$$

F2 = Main flow rate of BP (m^3/hr)

C1 = Neutralizing agent concentration (g/L)

TRO2 = Initial TRO value with water treated EL before de-ballasting process
(Refer to 2.2.4. to check detail information for setting method of TRO2)

T_{TRO3} = Target TRO value at de-ballasting process (Setting value)

N1 = Parameter (Calculated ideal)
N2 = Experimental efficiency (Setting value)
N3 = Estimated between Measuring TRO2 and T_{TRO3}
Control variable in program (Default=1)
TRO3 = Measuring TRO value TRO sensor during de-ballasting process

If (T_{TRO3} – TRO3) > 0 or positive (+) ⇒ NAP flow rate increase (Calculating with TRO3 and T_{TRO3} value)
If (T_{TRO3} – TRO3) < 0 or negative (-) ⇒ NAP flow rate decrease (Calculating with TRO3 and T_{TRO3} value)

2.2.1.4. Setting method of TRO2 value
(Initial TRO value for de-ballasting operation)

1) De Initial TRO (A)

- A new TRO sensor which measures TRO concentration with water before neutralization is added at existing model of AquaStar™ BWMS.
- This method is used to reduce the initial consumption of a neutralizing agent.
- This method is upgraded at interval measuring and cycle measuring.

① Before de-ballasting operation, touch A button in the screen of "navigation process (Above picture)".

② Set a target TRO3 value in the screen of "deballast set".

③ Stat BP and de-ballasting operation is automatically started.

④ De-ballasting operation is conducted on condition that target TRO1 setting at ballasting operation is applied as the initial TRO2 at neutralization equation during setting period.

⑤ During setting period, TRO concentration with water before neutralization is measured by new added TRO sensor.

⑥ After setting period, the average value of measured values (⑤ step) is applied as the initial TRO2 at neutralization equation.

⑦ The suitable volume of a neutralizing agent is injected during de-ballasting operation.

2) Manual Set (B)

- The initial TRO2 is directly or manually setting by the operator.
- Source of a initial TRO2
  a. Default supplied AQUA Eng. Co., Ltd
  b. Actual measured value by TRO portable at site
     (Sampling water before neutralization)

① Before de-ballasting operation, touch B button in the screen of "navigation process (Above picture)".

② The operator directly sets the initial TRO2.

③ Set a target TRO3 value in the screen of "deballast set".

④ Stat BP and de-ballasting operation is automatically started.

⑤ If the measured TRO > target TRO, the flow rate of NAP is increased.
If the measured TRO < target TRO, the flow rate of NAP is decreased.
→ This process is automatically controlled and monitored.

3) Interval Measuring (C)

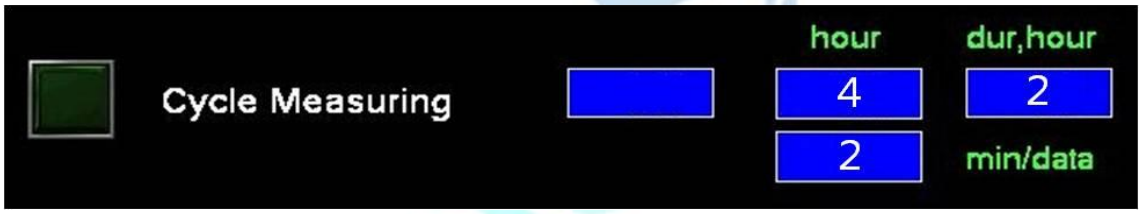
- After stopped ballasting operation, the power of AquaStar™ BWMS is shut off.
- To check the initial TRO2 before de-ballasting operation, turn on the power of AquaStar™ BWMS.
- Such as below picture, the operator sets the setting time to measure TRO concentration with water before neutralization.

Ex) Power on the system

→ Measure TRO concentration per 2 minutes during 2 hours after 4 hours

4) Cycle Measuring (D)

- The situation of power on for AquaStar™ BWMS all the time
- This method is used to check the initial TRO2 before de-ballasting operation or monitor the change of TRO concentration after ballasting operation.
- Such as below picture, the operator sets the setting time to measure TRO concentration with water before neutralization.



Ex) Measure TRO concentration per 2 minutes during 2 hours per 4 hours

2.2.2. PID control

PID control is applied to control the TRO value in the system.
In the method of PID control, the control method by the continuous analog value is not suitable for a measuring method or a control method in the system. Thus, the system is applied to PID control of the sampling method (the discrete value).

First, the basic equation for PID control of the sampling method is described in the reaction 1.

(Reaction 1)

Manipulated variable = K_p×a deviation (Proportional) + K_i×a cumulative value of a deviation (Integral) + K_d×a differential value with the last deviation (Differential)

When expressing by symbols

$$TCn = TC_{n-1} + \Delta TC_n$$

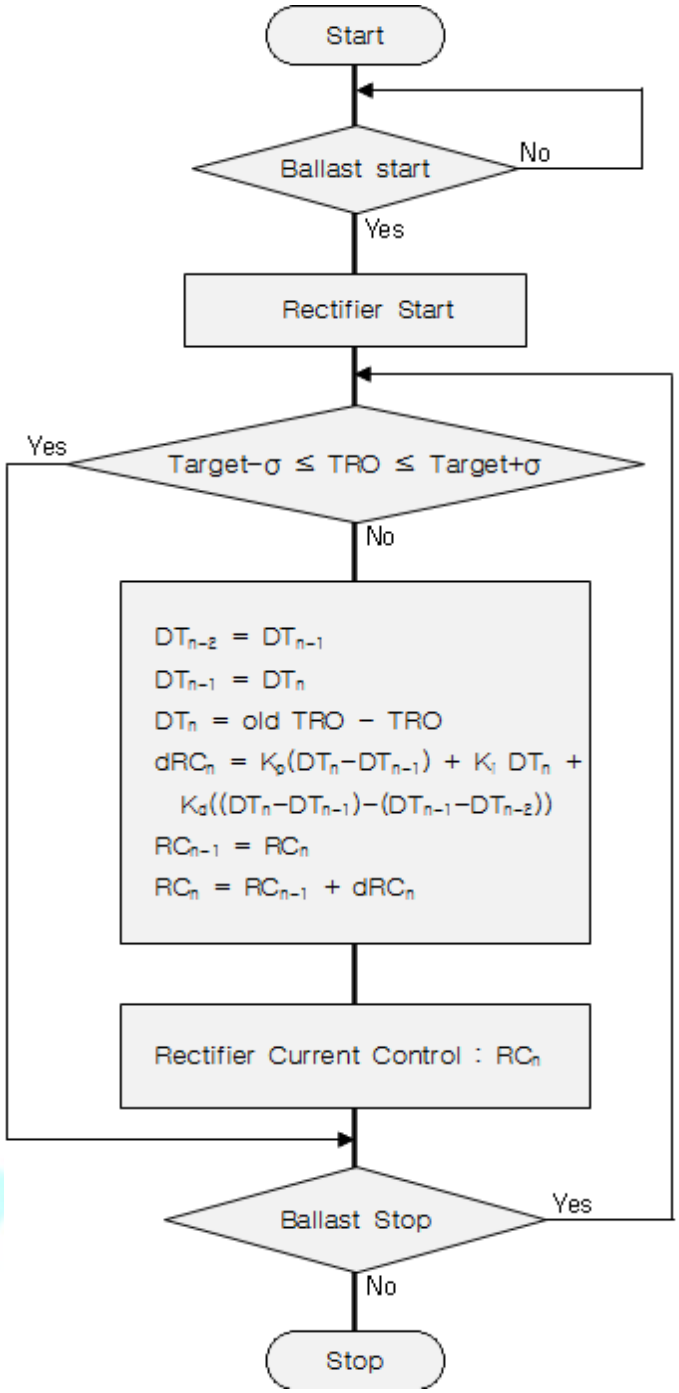
$$\Delta TC_n = K_p(DT_n-DT_{n-1}) + K_i\, DT_n + K_d\{(DT_n-DT_{n-1})-(DT_{n-1}-DT_{n-2})\}$$

TC_n, TC_{n-1} : n, n-1 th control variable

ΔTC_n : n th control variable differentiation

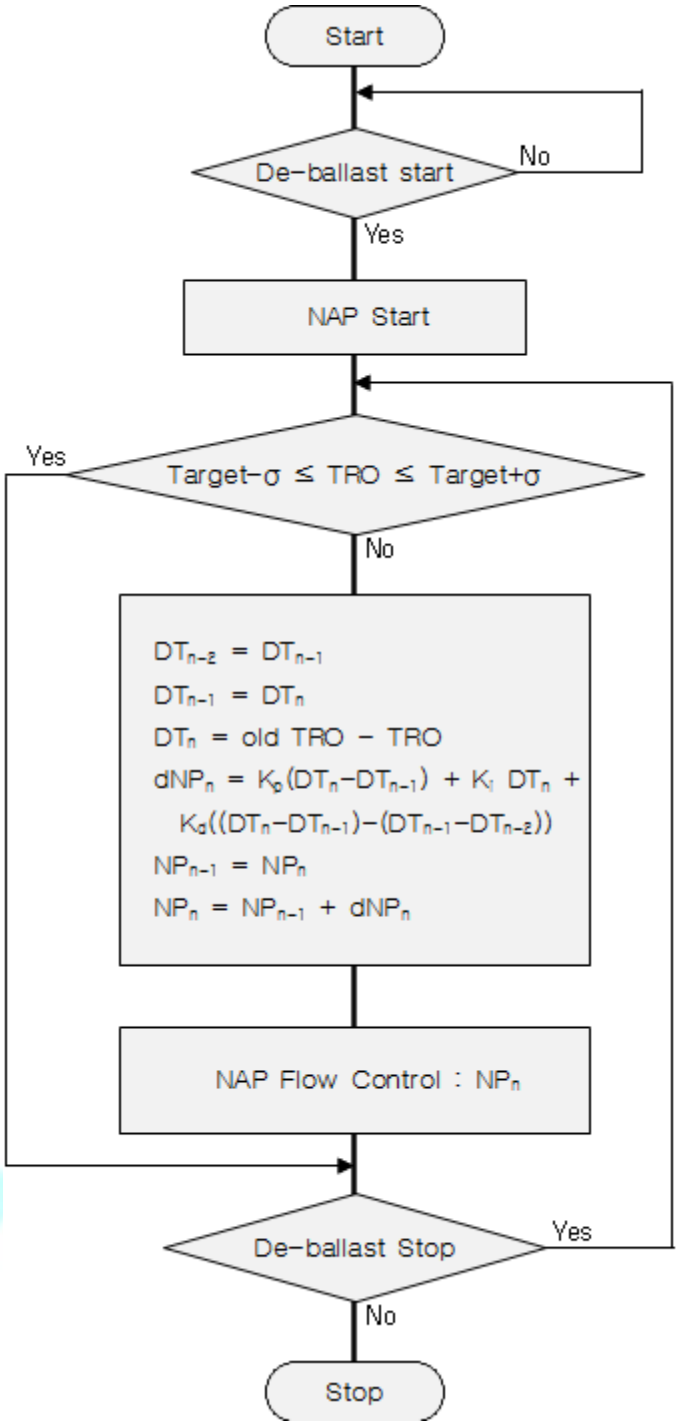
DT_n, DT_{n-1}, DT_{n-2} : n, n-1, n-2 th deviation

2.2.2.1. Ballasting control



- RC_n, RC_{n-1} : n, n-1 th control variable of Rectifier
- dRC_n : n th control variable differentiation of Rectifier
- DT_n, DT_{n-1}, DT_{n-2} : n, n-1, n-2 th deviation

2.2.2.2. De-ballasting control

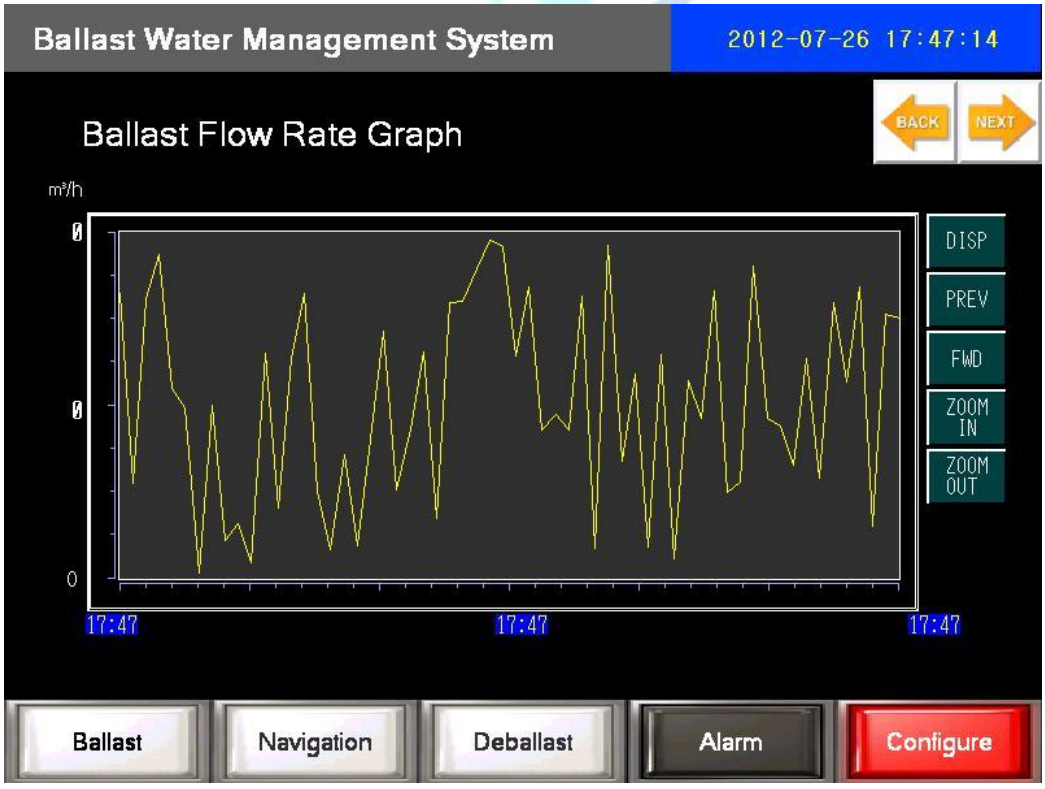


- NP_n, NPC_{n-1} : n, n-1 th control variable of NAP
- dNP_n : n th control variable differentiation of NAP
- DT_n, DT_{n-1}, DT_{n-2} : n, n-1, n-2 th deviation

2.2.3. Continuous self-monitoring

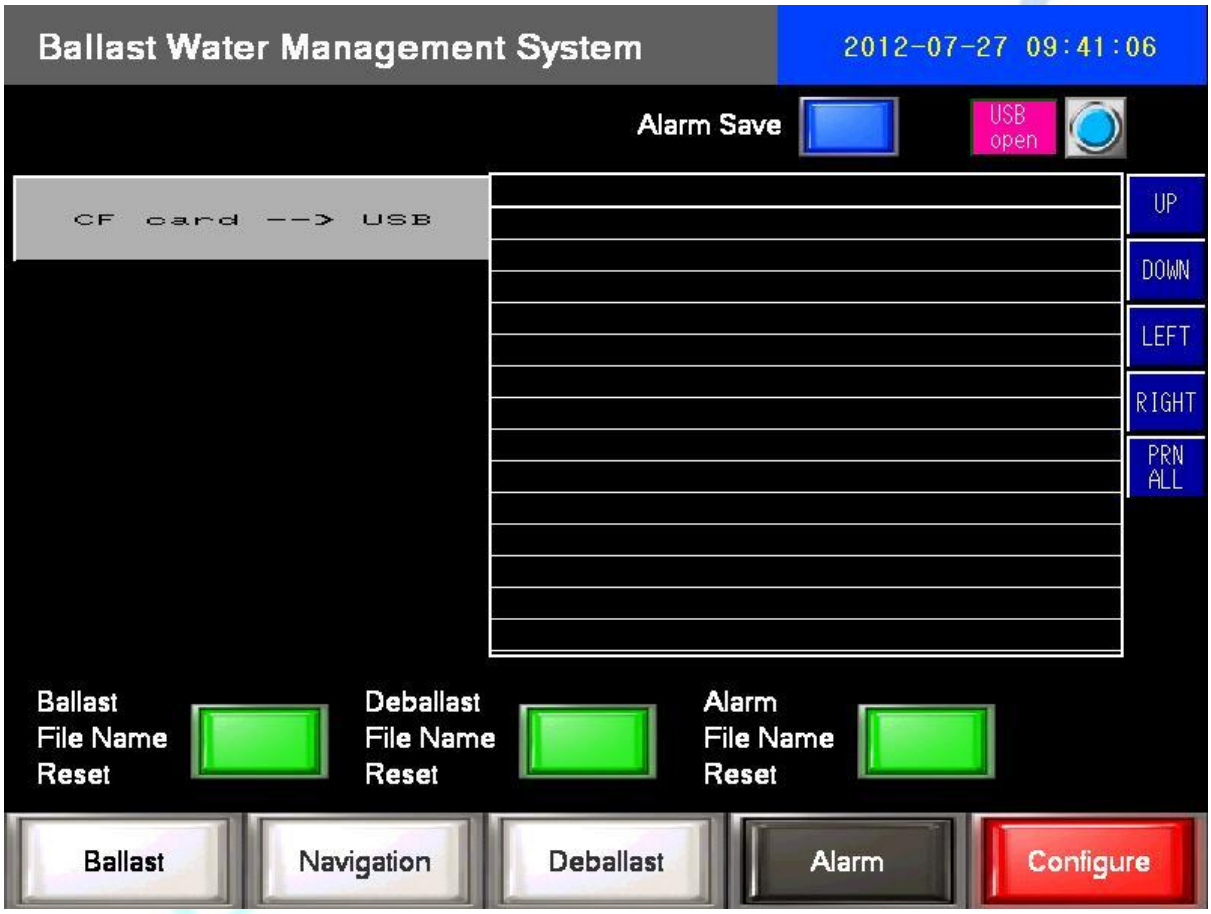
By controlling and monitoring the ballasting and de-ballasting control of CSU, the operation of AquaStar™ BWMS is to continuous self-monitoring.
In ballasting and de-ballast process screen of MCP or LCP, each unit is touched, the measured value for this unit is appeared (Real-time monitoring=History graph).
History graphs of each unit;

- Main flow-rate of ballasting de-ballasting process
- Voltage/ampere and temperature of rectifier
- Voltage/temperature of EL
- TRO sensor
- Pressure_SP / Pressure_NU
- CL2D, H2D
- NT level



2.2.4. Data storage

When touch the data management button of data save set screen in configure screen, the data management screen appears as shown.
All operation data (ballasting/de-ballasting process) are automatically stored at the memory card (CF card) in touch panel of CSU, while CSU is power on.
Also, alarm list and instrument state are stored in touch panel of CSU.



Please, refer to Appendix C-3 (Data logging) to check the storage form for operation, alarm and instrument data.

<The method to check the data stored in CSU>

① Touch the words (CF card) in above screen.
② Some folders is appears as SAMP 01 (alarm), SAMP 02 (operation data) and SAMP 03 (instrument state).
③ When touch the name of folder that want to the check, every file is appears in order created.
④ When touch the name of file that want to the check, operation data is appears in right table.
⑤ Using up, down, left and right button, detailed data value can be verified.

※ When touch the button (file name reset), number of new file's name is relisted from "0".

※ When touch the button (alarm save), save the list of alarm that occurred until now.

<The method of download the data from CF card in touch panel to USB memory>

① Put the USB memory into the touch panel.
② In the file list of CF card, select and touch the file that want to the download.
③ Touch the COPY button in lower left of the table. And, select the YES about question of program.
④ Touch the PASTE button in lower left of the table. And, select the YES about question of program.
⑤ After download the file, touch the button (USB open) before pull the USB memory.
⑥ Pull the USB memory from the touch screen.
⑦ Check the operation data of the USB memory.

※ Check procedure of previous operation data, after MCP replacement

① After new MCP replacement same as model, remove the storage media put the predecessor, and then put at new MCP

② MCP power on

③ Check the previous operation data at MCP display

④ To print the previous operation data, do the method indicated "The method to check the data stored in MCP"

※ Operation data capacity

Total data capacity for operation (ballasting and de-ballasting), alarm and instrument state: 28~30KB/h

As calculating for years,

→ 478~512MB/2years

Because the data capacity of a storage media supplied from AquaStar™ BWMS is 4GB, the data storage is enough for 2 years.

2.2.5. Safety function

In AquaStar™ BWMS, various sensors (such as MFM, CM, TT, PI, TBS, TRO sensor, H2D, CL2D, LT and LG) are installed for the effective operation of AquaStar™ BWMS. During AquaStar™ BWMS operation, these sensors can be detected any risk factors. Depending on the level of a sensed risk, CSU is programmed to be able to conduct the proper response.

In the maintenance for AquaStar™ BWMS, audible and visual alarm signals are activated whenever the BWMS is in the operation for purposes of management (cleaning, calibration and repair) and ballasting or de-ballasting; such events recorded by CSU.

All components of AquaStar™ BWMS can't be installed in the explosive hazardous area. If you want to install in the explosive hazardous area, AquaStar™ BWMS certified Explosion-proof must be used.

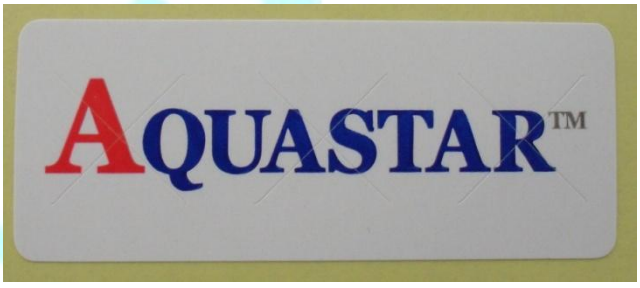
Alarm and Interlock list

Units	Installation	Alarm	Interlock
MFM			
1) Ballasting process (m^3/hr)	O	Low/High	Low Low/High High
2) De-ballasting process (m^3/hr)	O	Low/High	Low Low/High High
SP			
1) PI	O	X	X
2) PT (kg/cm^2)	O	High	High High
Electrolyzer system unit			
1) EL temp. (℃)	O	High	High High
2) EL voltage (V)	O	High	High High
3) Rectifier voltage (V)	O	High	High High
4) Rectifier ampere (A)	O	High	High High
5) Rectifier temp. (℃)	O	High	High High
6) TRO value (ppm)			
Ballasting process	O	Low/High	Low Low/High High
De-ballasting process	O	High	High High
Neutralization system unit			
1) NT level (%)	O	Low	Low Low
2) Flow rate	O	Low	Low Low
3) NU			
PI	O	X	X
PT (kg/cm^2)	O	High	High High
Others			
1) CM (mS/cm)	O	Low	Low Low
2) H2D (%)	O	High	High High
3) CL2D (ppm)	O	High	High High

2.3. Main components

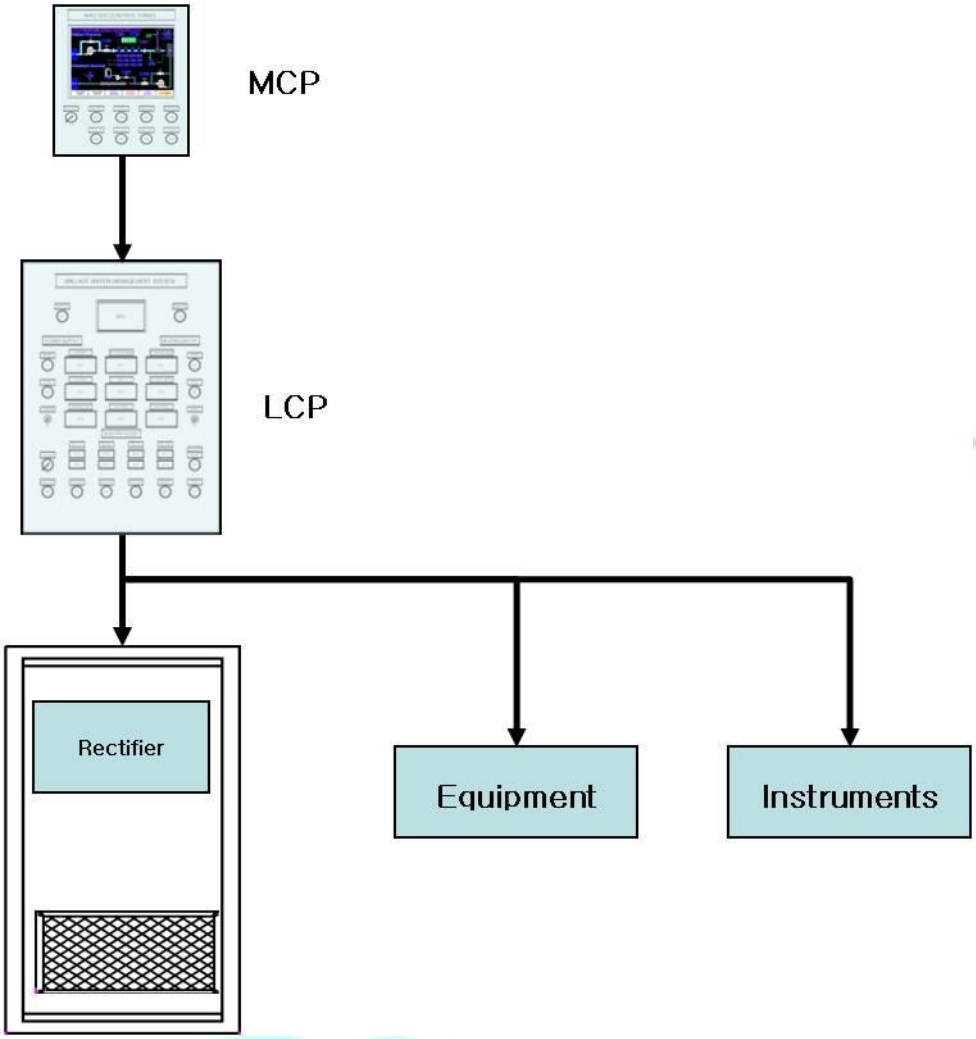
2.3.1. CSU

During ballasting and de-ballasting, the operation of the AquaStar™ BWMS is automatically monitored and controlled by CSU. CSU of the AquaStar™ BWMS is based on PLC and is designed as available equipment at vessel type.
CSU is used the operation of AquaStar™ BWMS and is composed of MCP and LCP.
MCP is installed at COC (Control room=Deck office) and takes over all unit operation and overall operation of AquaStar™ BWMS.
LCP is installed at the engine room and takes over emergency and local operation.
In order to protect, control and maintain the operation data or the soft program for CSU, the engineer of AQUA Eng. Co., Ltd. installed the security label (the breaking of a seal; see the below picture) at important parts (Cover, CF card and communication connecter etc.) of MCP and LCP, respectively.



< Seal sticker >

Configuration of CSU



2.3.1.1. MCP

MCP is applied to the control program designed AQUA Eng. Co., Ltd.

Functions of MCP are as follows;

- Auto and manual operation for ballasting and de-ballasting
- The display and storage of operation data communicated with LCP
- The display and storage of parameter operation
- The setting of safety conditions (Alarm and Interlock)
- Check operation state of all instruments and equipment

Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

2.3.1.2. LCP

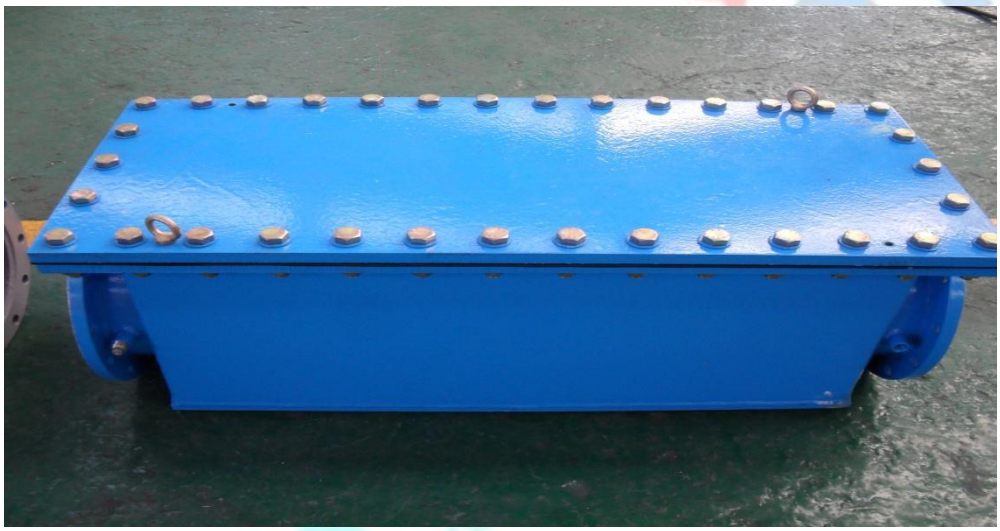
LCP is applied to the control program designed AQUA Eng. Co., Ltd.
Functions of LCP are as follows;

- Auto and manual operation for ballasting and de-ballasting
- The display and storage of operation data communicated with all instruments and equipment
- Transfer the operation data into MCP
- The display and storage of parameter operation
- The setting of safety conditions (Alarm and Interlock)
- Check operation state of all instruments and equipment
- Directly handle to equipment and instruments

Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

2.3.2. SP

SP is constructed with a number of half-baffle compartments with 50 μm mesh. When seawater and brackish water flow through SP, diverse flow types occur. When ballast water flows through SP, aquatic organisms larger than 50 μm are removed or damaged cell structures (such as membranes, appendages etc.).
Although some filters have clogged, the entire SP does not completely clog. If meshes are partially clogged, clog reducing mechanism is occurred by the back-flow of running fluid in an inside of SP.



Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

2.3.3. Electrolyzer system unit

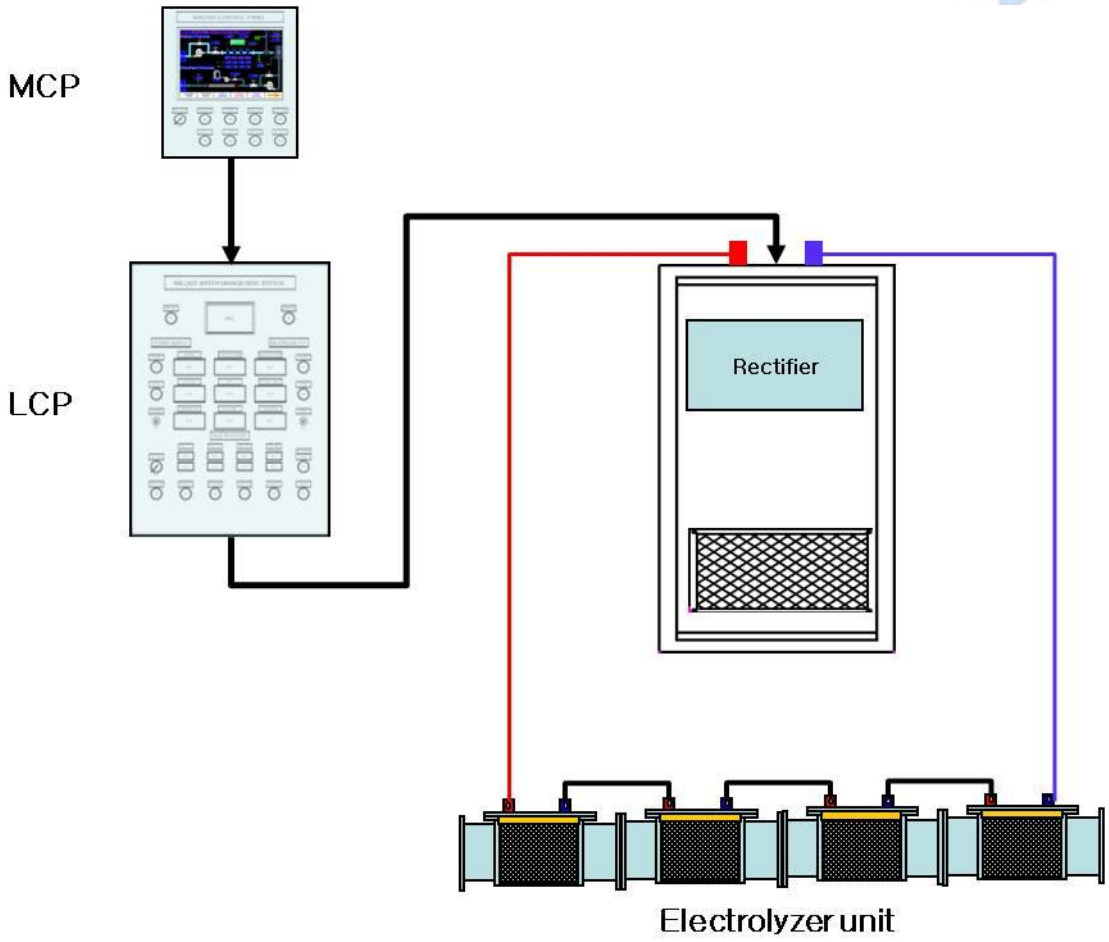
Components of Electrolyzer system unit are as following;

- Rectifier
- EL
- GS (including AB, AAV etc.)

During ballasting operation, EL electrolyzes the natural seawater and brackish water based on electrolysis method. EL disinfects harmful aquatic organism including the seawater and is suitable to IMO D-2 Regulation.
When EL is operated, AQUA Eng. Co., Ltd. designed that TRO concentration is generated below 10 mg/L as Cl_2. Dependent on TRO value and ballast flow rate, the current supplied from rectifier is automatically controlled.

2.3.3.1. Configuration of Electrolyzer system unit

Rectifier is directly connected to LCP. The current supplied from rectifier is controlled by LCP. The amount of current is controlled by the change of generated TRO value. Based on this information transferred from CSU, the current of rectifier is controlled. Also, rectifier is connected with EL and supplies the current of the specified value to EL.



2.3.3.2. Rectifier

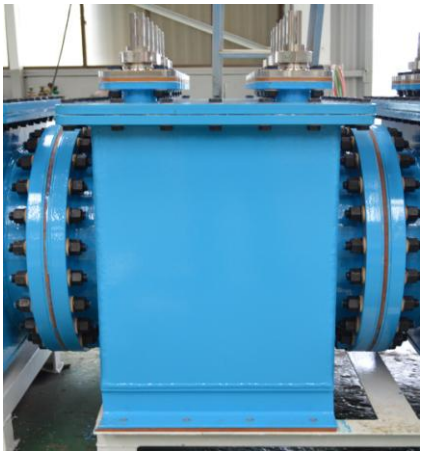
Rectifier (including RCP) is installed near EL at engine room and transfers from 440V AC supplied at MSBD to DC, and DC is supplied to EL. The generated heat during transferring form AC to DC is refrigerated by air flowing from the cooling fan. Dependent on the location of rectifier, the location of the BR using the electric wire connection is possible to design the installation of diverse parts (top/bottom, front/back) in ship.

Rectifier type applied AquaStar™ BWMS is IGBT rectifier and SCR rectifier. The type selection of these rectifiers is determined by site of vessel.

Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

2.3.3.3. EL

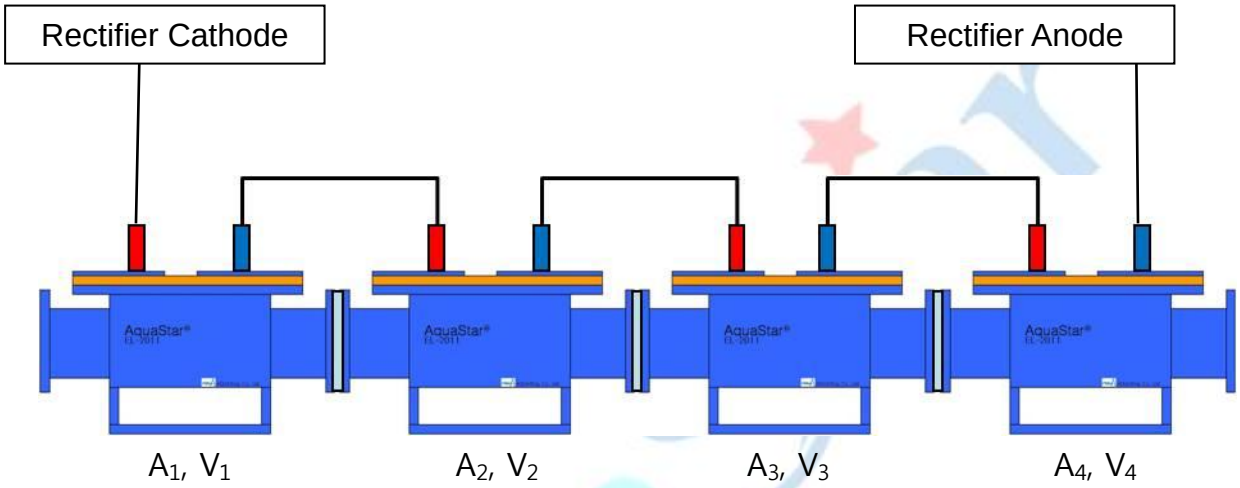
EL as an important part of AquaStar™ BWMS is installed in main stream of ballast pipe line and electrolyzed to form TRO of regular concentration. When EL operates using seawater or brackish water, TRO is generated. TRO concentration of the treated water is automatically monitored by CSU with a feed-back system for control of the rectifier in order to regulate TRO, and in turn the TRO concentration.



Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

EL serial connecting method

In AquaStar™ BWMS, being considered to low current operation and flexibility of installation, EL more than two set can be connected serially. Positive (+) BR of EL is connected with negative (-) BR of the neighbor EL. See the picture below.



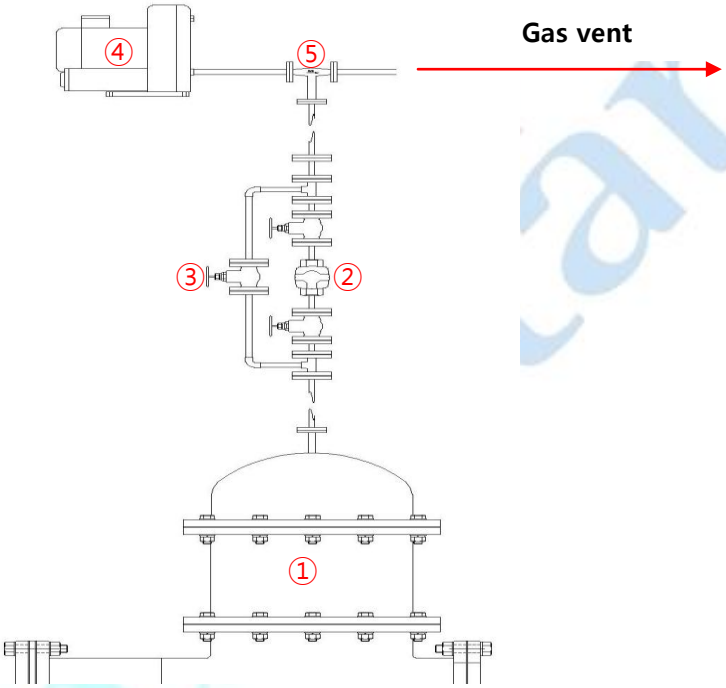
A_1, V_1 A_2, V_2 A_3, V_3 A_4, V_4

$$A_{total} = A_1 = A_2 = A_3 = A_4$$

$$V_{total} = V_1 + V_2 + V_3 + V_4$$

2.3.3.4. GS

In the ballasting process, hydrogen gas is generated during the operation of EL. GS is safely vented on hydrogen gas to the outside. AAV is installed the top of GS. When the air pressure increases over fixed extent, hydrogen gas is automatically vented.



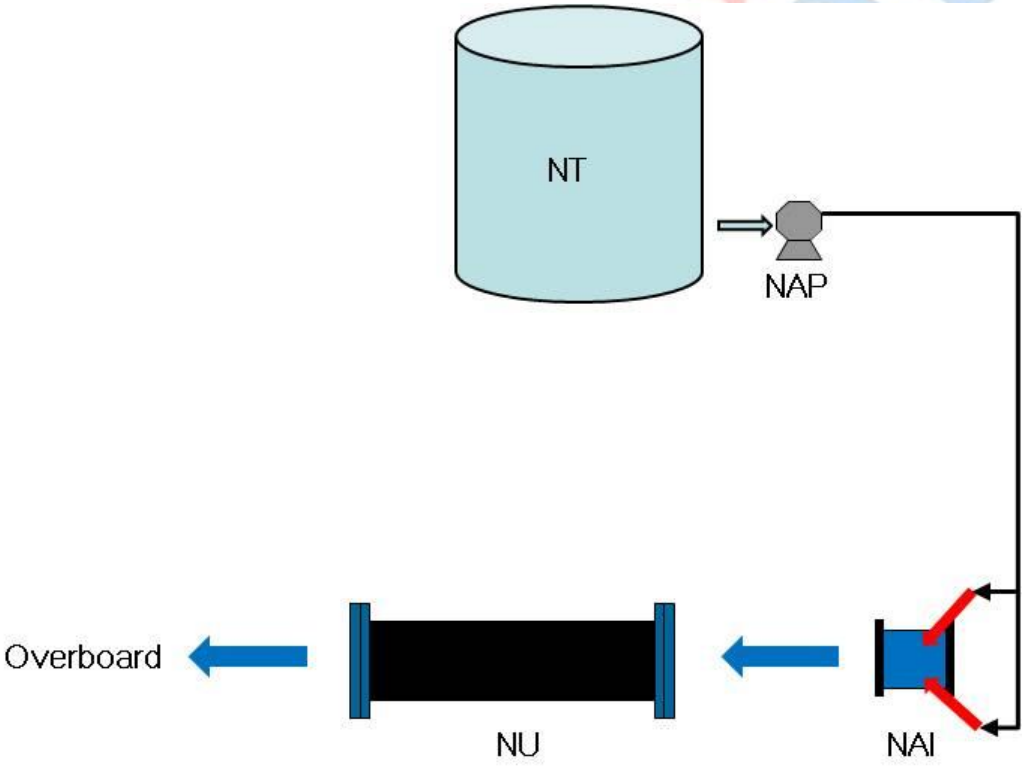
1: GS
2: AAV
3: By-pass line
4: AB
5: AV

Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

2.3.4. Neutralization system unit

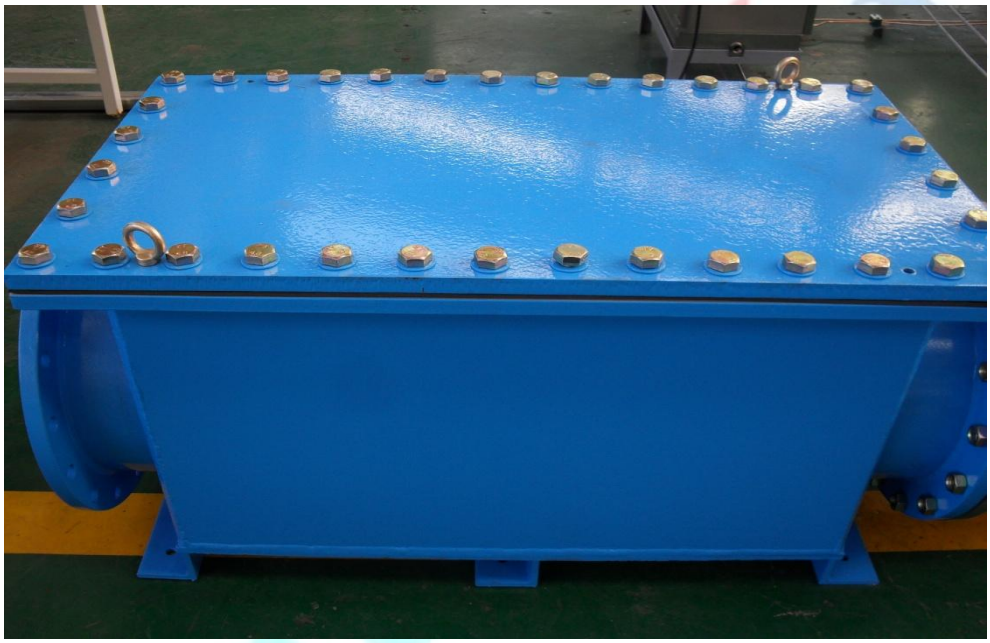
In the de-ballasting operation, Neutralization system unit removes TRO of treated water in the BT. TRO concentration of seawater treated by Neutralization system unit is similar to that of the natural seawater. Neutralization system unit is composed of NU, NT (1st and 2nd), NAP, NTP, NIP, NSPP and NCP.

Configuration of Neutralization system unit



2.3.4.1. NU

NU is installed in main stream of de-ballasting pipe line (Discharge pipe).
During de-ballasting, NU reduces TRO concentration of the treated water (Similar to TRO concentration of the natural seawater). TRO concentration is continuously monitored during de-ballasting operation and a feed-back system controls the injected amount of the neutralizing agent.

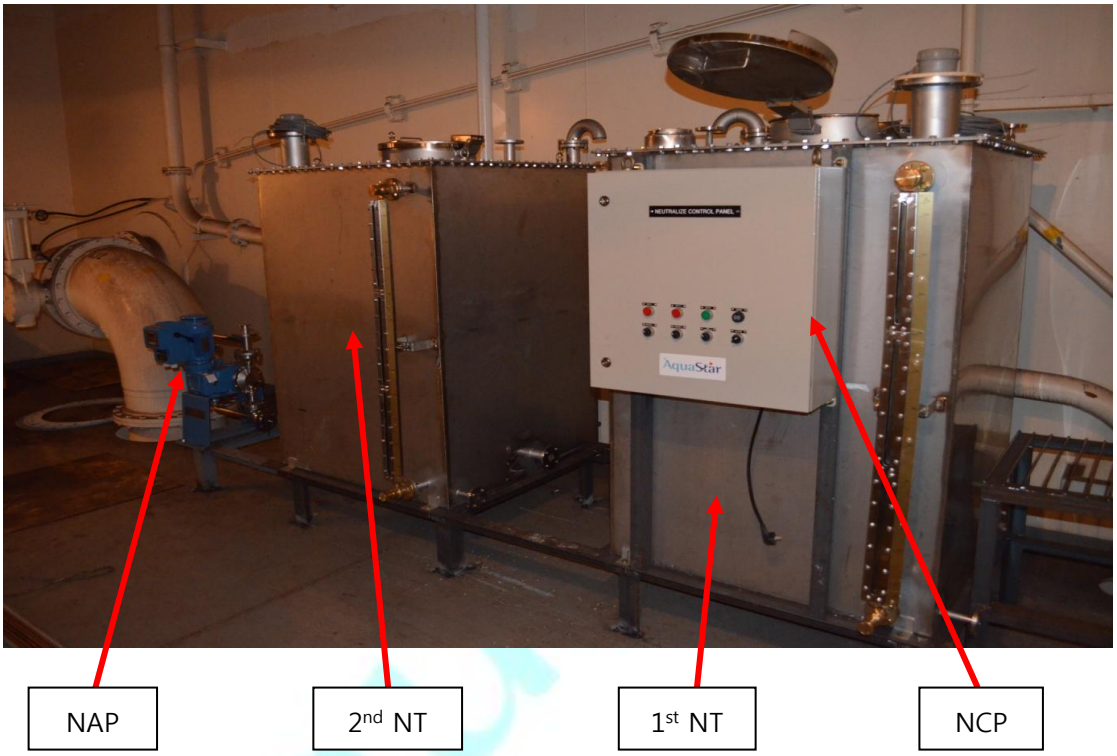


Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

2.3.4.2. NT

The air bubbling system using to solve the neutralizing agent is placed to the bottom inside NT.

NT is composed of 1st NT and 2nd NT.



- 1st NT
: Mixing a neutralizing agent (Solid type → Solution type)
- 2nd NT
: Supplying to a injector for a neutralizing agent

Also, LT and LG is installed in NT and is transferred the amount of neutralizing agent to CSU.

Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

2.3.5. Instruments

2.3.5.1. H2D/CL2D

During ballasting process, hydrogen (H_2) and chlorine (Cl_2) gas are generated by electrolysis. H2D and CL2D are installed to detect the leakage of hydrogen and chlorine gas.

- Installation location of gas detector

1) H2D (installed two points)
   - End part of air vent line connected GS and above part of near EL

2) CL2D (installed one point)
   - Below part of near EL

<TS-4000 (H_2)>

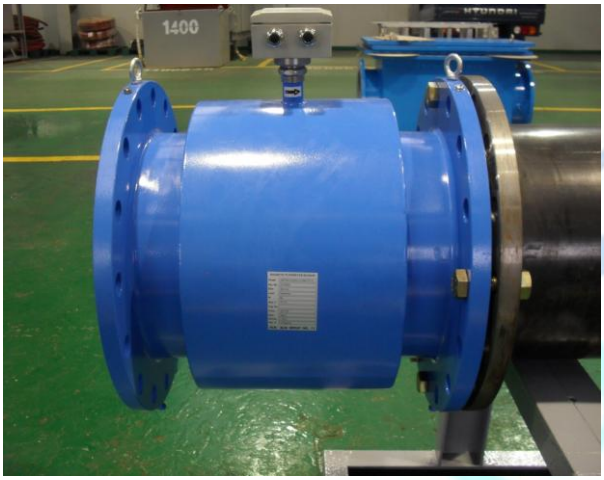
<GTD-1000Ex (H_2)>

<GTD-1000Tx (Cl_2)>

Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

2.3.5.2. MFM

MFM is directly installed at the main ballast pipe in the engine room and measures the flow rate of BP.
In ballasting process, MFM measures the normal direction flow. The measured flow value transfers to CSU and is utilized the current calculation of the rectifier.
In de-ballasting process, MFM measures the reverse direction flow. The measured flow value is transferred to CSU and is utilized the flow rate calculation of NAP.



Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

2.3.5.3. TRO sensor

AquaStar™ BWMS controls and measures TRO concentration using on-line type equipment (CLX-XT) adopted DPD method. Also, TRO sensor is installed at the engine room and connected with LCP. The measurement range for TRO sensor is designed as 0 ~ 10 mg/L as Cl_2, but TRO sensor is upgraded up to 15 mg/L as Cl_2.

1) Ballasting process
: Alarm and interlock setting value is setting for low and high TRO value.
- **Setting for low TRO value**

① When it is continuously two occurrences for less than 8 mg/L as Cl_2, alarm is operated at CSU.

② When it is continuously three occurrences for less than 8 mg/L as Cl_2, AquaStar™ BWMS is shutdown.

- **Setting for high TRO value**

① When it is continuously two occurrences for over than 10 mg/L as Cl_2, alarm is operated at CSU.

② When it is continuously three occurrences for over than 10 mg/L as Cl_2, AquaStar™ BWMS is shutdown.

2) De-ballasting process
: Alarm and interlock setting value is setting for high TRO value.
- Setting for high TRO value

① When it is to pass 240 seconds (Possible to set) for over than 0.15 mg/L as Cl_2, alarm is operated at CSU.

② When it is to pass 240 seconds (Possible to set) for over than 0.2 mg/L as Cl_2, AquaStar™ BWMS is shutdown.

Please, refer to Appendix C-1 (Operation Manual) to check detailed information for the specification of this unit.

2.3.6. Installation condition of main components

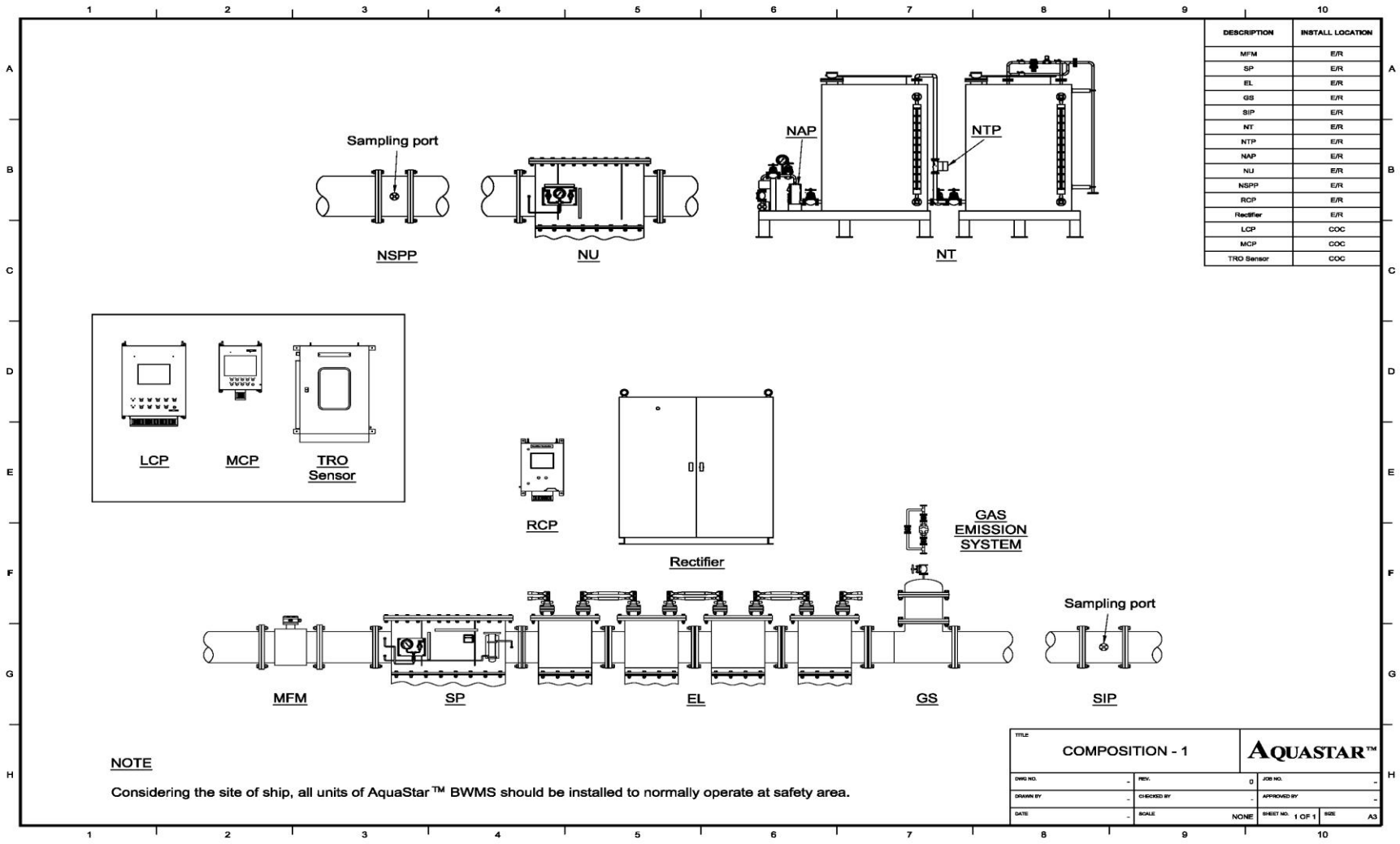
No.	Units	Installation location	Site	Remark
1	MCP	COC=Deck office	- Easily accessible place for ensuring safe operation	
2	LCP	Engine room	- Easily accessible place for ensuring safe operation	
3	SP	Engine room	- Ballast pipe forward 1st EL - Considered flow direction of BP	
4	Rectifier	Engine room	- Near EL - Security area from electric hazard	
5	RCP	Engine room	- Near Rectifier or LCP - Easily accessible place for ensuring safe operation	
6	EL	Engine room	- Ballast pipe between SP and GS at security area - Variable installation structure depending on the ship pipe line - Considered polar of EL	
7	GS	Engine room	- Ballast pipe backward 4th EL - Considered flow direction of BP	
8	SPP	Engine room	- Ballast pipe backward GS - Considered flow direction of BP	
9	NIP	Engine room	- Forepart of de-ballast pipe discharged from BT - Considered flow direction of BP	

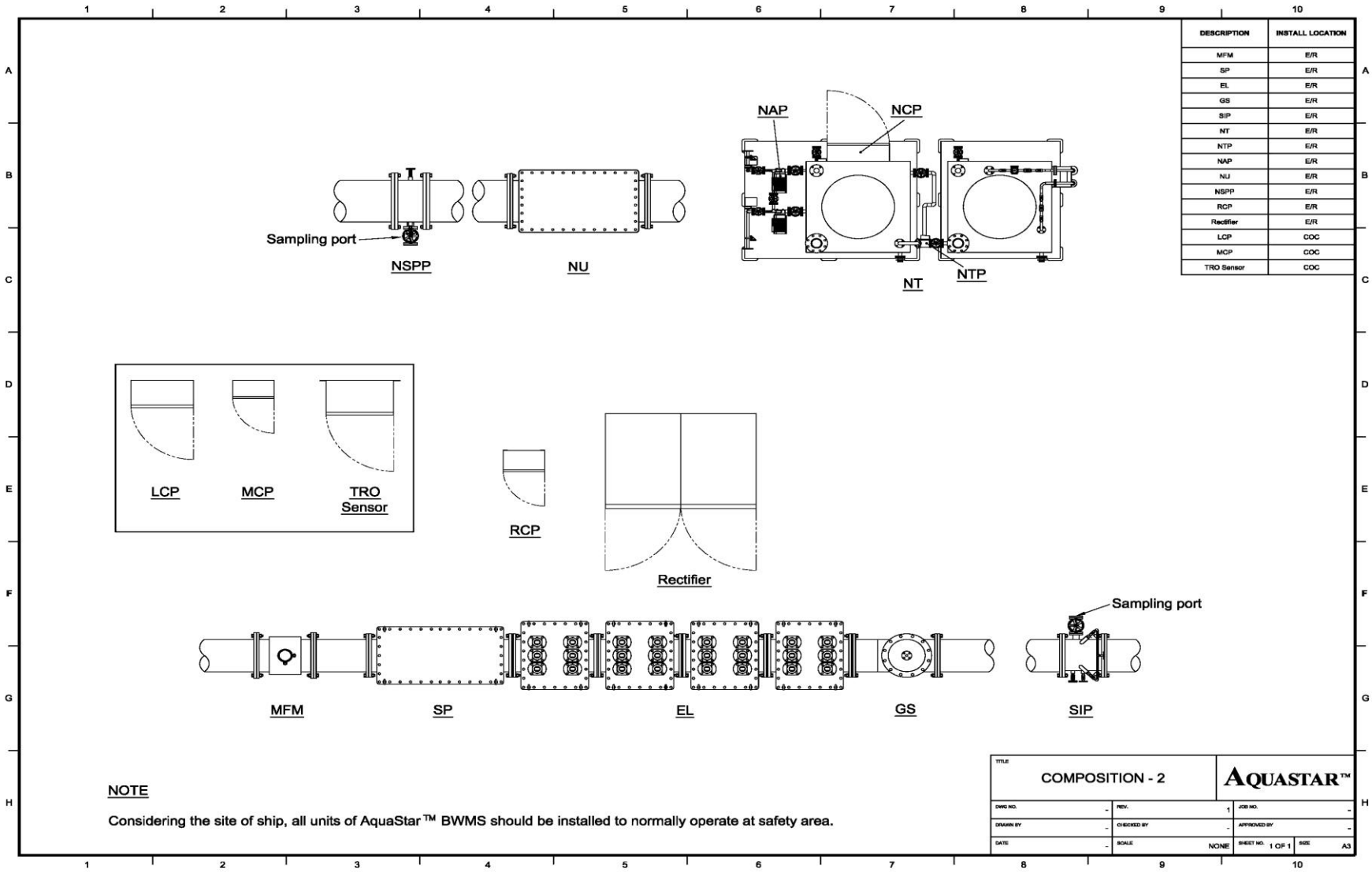
10	SIP	Engine room	- Unit combined SPP and NIP - Ballast pipe backward GS - Considered flow direction of BP	
11	NU	Engine room	- Variable installation structure depending on the ship pipe line - De-ballast pipe backward NIP - Considered flow direction of BP	
12	NT	Engine room	- Wide and easily accessible place	
13	NCP	Engine room	- Near NT - Easily accessible place for ensuring safe operation	
14	NAP	Engine room	- Near NT (2^{nd})	
15	NTP	Engine room	- Between 1^{st} NT and 2^{nd} NT	
16	NSPP	Engine room	- De-ballast pipe near overboard - Considered flow direction of BP	
17	MFM	Engine room	- Ballast pipe of back end of BP	
18	H2D	Over A or B deck	- End part of air vent line connected GS (Over A or B deck)	
19	CL2D	Engine room	- Below part near EL	
20	TRO sensor	Engine room	- Near LCP - Easily accessible place for ensuring safe operation	
21	CM	Engine room	- Near SP - Easily accessible place for ensuring safe operation	

- Considering the site of ship, all units of AquaStar™ BWMS should be installed to normally operate at safety area.
- Before installation at ship, the optimum installation location for all units of AquaStar™ BWMS should be selected by several inspections.

※ **Please, refer to below drawings to check installation and composition for each unit of AquaStar™ BWMS.**

Composition for each unit of AquaStar™ BWMS




DESCRIPTION
INSTALL LOCATION
MFM E/R
SP E/R
EL E/R
GS E/R
SIP E/R
NT E/R
NTP E/R
NAP E/R
NU E/R
NSPP E/R
RCP E/R
Rectifier E/R
LCP COC
MCP COC
TRO Sensor COC
Sampling port
NSPP
NU
NAP
NCP
NT
NTP
LCP
MCP
TRO Sensor
RCP
Rectifier
Sampling port
MFM
SP
EL
GS
SIP
NOTE
Considering the site of ship, all units of AquaStar™ BWMS should be installed to normally operate at safety area.
COMPOSITION - 2
AQUASTAR™
NONE
1 OF 1
A3

2.4. Pre-start check list

2.4.1. General hazard

2.4.1.1. Basic information

INSPECTION INFORMATION	
Project Name	:
Division	:
Inspector Name	:
Inspection Date	:

The function of this section is to determine the suitability whether design, construction, operation and function of BWMS is suitable for the standard of international convention and ship's voyage.
This section can be used as guidance for manufactures and ship's operator (crew) on the evaluation procedure that equipment will undergo and the requirements placed on BWMS.
Also, this section is used to maintenance for system including electric instruments.
All check lists of AquaStar™ BWMS indicated this document must be carried out by engineer of AQUA Eng. Co., Ltd.

2.4.1.2. Information for hazard substances

Please, list the surrounding hazard substances.

Fire/Explosion	
Gas	**:**
Liquid	**:**
Dust	**:**
Solid	**:**
Environmental health	**:**
Special ecology problem	**:**
Special corrosion problem	**:**

Note below any special hazards such as chemical reactivity, susceptibility to detonation, spontaneous combustion, human exposure.

2.4.2. Installation of main components

Division	Check item	Result
CSU		
MCP	1) Check the overall installation (No upper water leak or faller)	
	2) Check a fixing status	
	3) Check a power connecting status	
LCP	1) Check the overall installation (No upper water leak or faller)	
	2) Check a fixing status	
	3) Check a power connecting status	
SP		
SP	1) Check the overall installation	
	2) Check the water leakage (body, cover, flange and pipe line)	
	3) Check the welding status for socket	
	4) Check the installation direction (as same to ballast flow) as contrasted with drawing	
	5) Check a status of bolt fastened at cover, flange and bed	
	6) Check the assembly status and the welding with bed	
	7) Check the assembly and operation status of PTS related PI and PT	
	8) Check operation status for all valves	
Electrolyzer system unit		
Rectifier	1) Check the overall installation	

	(No upper water leak or faller)	
	2) Check a fixing status	
	3) Check a power connecting status	
	4) Check connection status of each rectifier and RCP	
	5) Check connection and communication status with PWD	
EL	1) Check the overall installation	
	2) Check the water leakage (body, cover and flange)	
	3) Check the assembly status for insulation bolt	
	4) Check the installation direction (as same to ballast flow) as contrasted with drawing	
	5) Check the assembly status for EL and bed	
	6) Check the insulted status between EL and bed	
	7) Check the assembly status for sealing device	
	8) Check the assembly status for EL and cover	
	9) Check the insulted status between 4ea EL	
	10) Check the assembly location of 4ea EL : Check positive and negative connecting of each EL	
	11) Check a status of flange assembly of each EL	
	12) Check a connecting status for cable between each EL	
	13) Check a connecting status for cable between rectifier and EL	
	14) Check a status related to applying the electric current for positive and negative of each EL	
GS	1) Check the overall installation	

	2) Check the installation direction as contrasted with drawing	
	3) Check the water leakage (body, cover, flange and pipe line)	
	4) Check the assembly status for valves and flanges related to gas vent line	
	5) Check the assembly status and location for AB	
	6) Check the assembly status and location for AV	
	7) Check the assembly status and location for AAV	
	8) Check a status of flange assembly of GS	
	9) Check the outlet status of gas vent line installed higher than upper deck in the safety area	
	10) Check operation status for all valves	
Neutralization system unit		
NU	1) Check the overall installation	
	2) Check the water leakage (body, flange and pipe line)	
	3) Check the welding status for socket	
	4) Check the installation direction (as same to flow) as contrasted with drawing	
	5) Check a status of bolt fastened of flange	
	6) Check the assembly status for socket and ball valve	
	7) Check operation status for all valves	
	8) Check the assembly and operation status of PTS related PI and PT	
NT	1) Check the overall installation	
	2) Check the water leakage of NT	

	3) Check the water leakage of pipe line related to NT	
	4) Check the installation status of LG and LT	
	5) Check the installation status of FWSS	
	6) Check the installation status of ASS	
	7) Check the installation status of NAP	
	8) Check the installation status of NTP	
	9) Check the installation and operation status of PI for NAP	
	10) Check operation status for all valves	
NCP	1) Check the overall installation (No upper water leak or faller)	
	2) Check a fixing status	
	3) Check a power connecting status	
NIP	1) Check the overall installation	
	2) Check the water leakage (body, flange and pipe line)	
	3) Check a status of bolt fastened at flange	
	4) Check the installation direction (as same to flow) as contrasted with drawing	
	5) Check operation status for all valves	
SIP	1) Check the overall installation	
	2) Check the water leakage (body, flange and pipe line)	
	3) Check a status of bolt fastened at flange	
	4) Check the installation direction (as same to flow) as contrasted with drawing	
	5) Check operation status for all valves	

SPP	1) Check the overall installation	
	2) Check the water leakage (body, flange and pipe line)	
	3) Check a status of bolt fastened at flange	
	4) Check the installation direction (as same to flow) as contrasted with drawing	
	5) Check operation status for all valves	
NSPP	1) Check the overall installation	
	2) Check the water leakage (body, flange and pipe line)	
	3) Check a status of bolt fastened at flange	
	4) Check the installation direction (as same to flow) as contrasted with drawing	
	5) Check assemble and operation status for all valves	
Instruments		
MFM	1) Check the overall installation (No upper water leak or faller)	
	2) Check the water leakage (body and flange)	
	3) Check a status of bolt fastened at flange	
	4) Check the installation direction (as same to ballast pump flow) as contrasted with marker manual	
	5) Check the installation and fixing status of transmitter	
	6) Check cable connection status of transmitter and body	
	7) Check ground connection status	

H2D /CL2D	1) Check the overall installation (No upper water leak or faller)	
	2) Check the installation and fixing status	
	3) Check ground connection status	
TRO sensor	1) Check the overall installation (No upper water leak or faller)	
	2) Check the water leakage (TRO sensor and pipe line)	
	3) Check a fixing status	
	4) Check a connecting status of pipe lines (sampling)	
	5) Check assemble and operation status for all valves	
	6) Check volume and condition state for reagent and buffer bottle	
Butterfly valve (Main and by-pass valves)	1) Check the overall installation (No upper water leak or faller)	
	2) Check the installation and fixing status	
	3) Check the water leakage	
	4) Check a status of bolt fastened at flange	
	5) Check the installation direction (as same to ballast pump flow) as contrasted with marker manual	
CM	1) Check the overall installation (No upper water leak or faller)	
	2) Check the installation and fixing status	
	3) Check the water leakage	

FS (Option; Explosion-proof type)	1) Check the overall installation (No upper water leak or faller)	
	2) Check the installation and fixing status	
	3) Check the water leakage	
Remark (Describe, if the inadequate state exists, except inspection items)		

2.4.3. Check list for electrical operation state

Division	Check points	Result
CSU		
MCP	State of power supply	
	Operation state of button/switch/lamp/touch screen of ballasting	
	Operation state of button/switch/lamp/touch screen of de-ballasting	
	Operation state of button/switch/lamp/touch screen of navigation	
	Operation state of emergency switch	
	Operation state of emergency operation switch	
	Communication state with LCP	
LCP	State of power supply	
	Operation state of button/switch/lamp/touch screen of ballasting	
	Operation state of button/switch/lamp/touch screen of de-ballasting	
	Operation state of button/switch/lamp/touch screen of navigation	
	Operation state of emergency switch	
	Communication state with MCP/instruments/equipment	

SP		
SP	Communication state of PT_4~20 mA	
Electrolyzer system unit		
Rectifier	State of power supply	
	Operation and communication state of RCP	
	Operation state of TT	
	Operation state of voltage and current	
	Operation state of emergency switch	
	Communication state with LCP	
EL	Operation state of TT	
	Operation state of TBS	
	Operation state of voltage	
GS	Operation state of AB	
	Operation state of solenoid valve	

Neutralization system unit		
NU	Communication state of PT_4~20 mA	
NCP	State of power supply	
	Operation state of button/switch/lamp	
	Communication state of LT_4~20 mA	
	Communication state with LCP/instruments	
NT	Operation state of ASS	
	Operation state of FWSS	
	Operation state of solenoid valve	
NAP	State of power supply	
	Operation state of output (flow rate)	
	Operation state of button	
NTP	State of power supply	
	Operation state of this device (flow)	

Instruments		
MFM	State of power supply	
	Communication state with LCP	
	Communication state for 4~20 mA	
	Operation state of button	
H2D	Communication state with LCP	
	Communication state for 4~20 mA	
CL2D	Communication state with LCP	
	Communication state for 4~20 mA	
TRO sensor	State of power supply	
	Communication state with LCP	
	Communication state for 4~20 mA	
	Operation state of this device	
	Operation state for cooling system	
	Operation state of solenoid valve	
	Operation state for suction pump	
Butterfly valve (Main and by-	Communication state with LCP	

pass valves)	Operation state of this device	
CM	State of power supply	
	Communication state with LCP	
	Operation state of this device	
	Communication state for 4~20 mA	
FS (Option; Explosion-proof type)	Communication state with LCP	
	Operation state of this device	
	Communication state for 4~20 mA or contact status indication signal	

2.4.4. Equipment test

Equipment list for work procedure

- **SP**
- **EL and GS**
- **NU, NT, NIP and NSPP**

Test report of manufacture

Equipment Name	**:**		
Model No.	**:**		
Drawing No.	**:**		
Inspector	**:**	**Date**	**:**

Inspection items	Test equipment	Result
Size inspection	Visual inspection/Digital level	
Welding inspection	UT tester	
Flange angular test	Digital level/Goniometer	
Painting inspection	Thickness gauge	
Assembling inspection	Visual inspection	
Insulation test	Multimeter	
Hydraulic test	Hydraulic pressure measuring device	
Remark (Describe, if the inadequate state exists, except inspection items)		

2.4.5. Emergency operation test

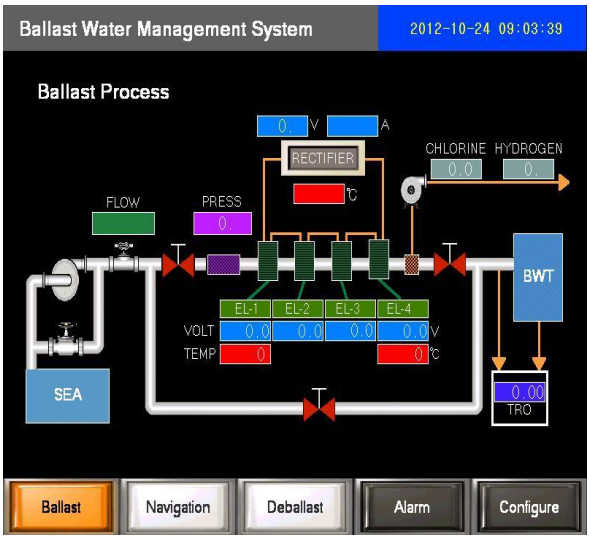
Abnormal operation test

Division	Performance checks	Result
Emergency switch test of MCP / LCP		
	Check rectifier power off Check BP stop (Option) Check ON state of instruments and equipment	
Alarm/Shut-down		
	Check alarm/interlock range of each instrument Refer to 2.5.4 (Alarm and interlock list)	
Remark (Describe, if the inadequate state exists, except inspection items)		

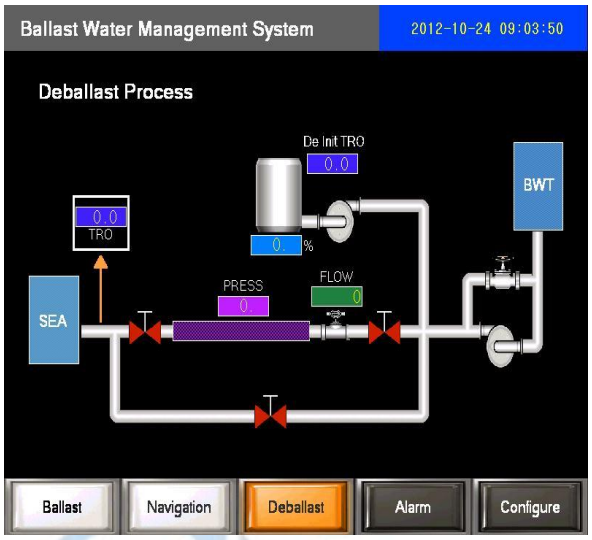
By-pass/Override test

Division	Performance checks	Result
By-pass procedure		
	By-pass valve open Main valves close Push emergency operation button of MCP BP start	
Check list for by-pass operation		
	Indication of valves position Rectifier power off Operation data storage	
Remark (Describe, if the inadequate state exists, except inspection items)		

2.4.6. Test run for the system

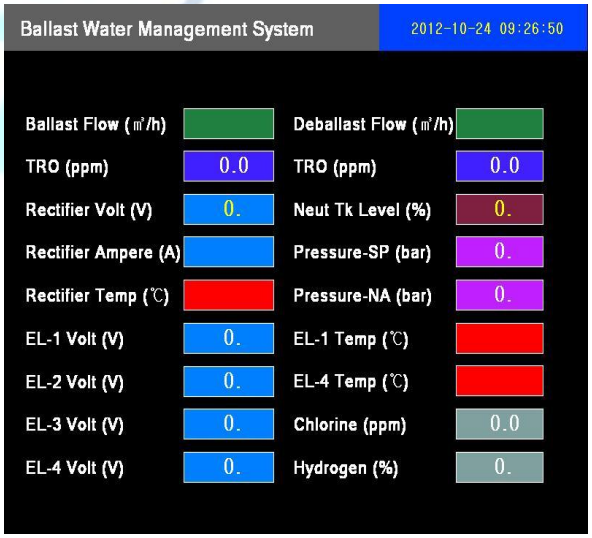


A: Ballasting process



B: De-ballasting process

C: Sensor status



D: Measuring value screen

2.4.6.1. Automatic ballasting operation

<table>
<tr><th>Division</th><th>Performance checks</th><th>Result</th></tr>
<tr><td>Preparation for operation</td><td>1) Check reagents preparation for TRO sensor</td><td></td></tr>
<tr><td>Condition for normal operation</td><td>1) Check normal operation state of MCP/LCP (Figure A)
2) Check communication with MCP, check each instruments (Figure C)
3) Check normal operation state of MFM (Figure C)
4) Check TRO sensor communicate with LCP (Figure C)
5) Check normal operation state of rectifier power on (Figure C)
6) Check state of main valves open (Figure A)
7) Check state of by-pass valve close (Figure A)</td><td></td></tr>
<tr><td>Check operation procedure</td><td>1) MSBD Power On
2) MCP/LCP Power On
3) BP start</td><td></td></tr>
<tr><td>Check normal condition for ballasting operation</td><td>
<table>
<tr><th>No</th><th>Instrument</th><th>Normal operation range</th></tr>
<tr><td>1</td><td>MFM</td><td>10 % ~ 110 % of Max. capacity</td></tr>
<tr><td>2</td><td>SP pressure</td><td>< 5 kg/cm^2</td></tr>
<tr><td>3</td><td>EL temp.</td><td>< 70 ℃</td></tr>
</table>
</td><td></td></tr>
</table>

	4	EL voltage	< 6 V	
	5	Rectifier voltage	< 24 V	
	6	Rectifier current	< 80 % of Max. capacity	
	7	Rectifier temp.	< 80 ℃	
	8	H2D	< 25 % of LEL	
	9	CL2D	< 0.5 ppm	
	10	TRO	8 ~ 10 ppm	
	11	CM	> 10 mS/cm	
	Check above items using figure A or D (Display of MCP/LCP)			
Ending procedure	1) BP stop 2) MCP/LCP Power Off 3) MSBD Power Off			

2.4.6.2. Automatic de-ballasting operation

Division	Performance checks	Result
Preparation for operation	1) Check preparation for neutralizing agent	
Condition for normal operation	1) Check normal operation state of MCP, LCP and NCP (Figure B) 2) Check communication with MCP, check each instruments (Figure C) 3) Check normal operation state of MFM (Figure C) 4) Check TRO sensor communicate with LCP (Figure C) 5) Check normal operation state of NAP (Figure B) 6) Check state of main valves close (Figure B) 7) Check state of by-pass valve open (Figure B)	
Check operation procedure	1) MSBD Power On 2) MCP/LCP/NCP Power On 3) Push de-ballasting button of MCP 4) BP start	

<table>
<tr>
<td>Check normal condition for de-ballasting operation</td>
<td>
<table>
<tr><th>No</th><th>Instrument</th><th>Normal operation range</th></tr>
<tr><td>1</td><td>MFM</td><td>10 % ~ 110 % of Max. capacity</td></tr>
<tr><td>2</td><td>NU pressure</td><td>< 5 kg/cm^2</td></tr>
<tr><td>3</td><td>NT level</td><td>> 30 %</td></tr>
<tr><td>4</td><td>TRO</td><td>< 0.15 ppm</td></tr>
<tr><td colspan="3">Check above items using figure B or D (Display of MCP/LCP)</td></tr>
</table>
</td>
<td></td>
</tr>
<tr>
<td>Ending procedure</td>
<td>1) BP stop
2) MCP/LCP/NCP Power Off
3) MSBD Power Off</td>
<td></td>
</tr>
</table>

2.4.6.3. Check items of ballasting/de-ballasting operation data

Division	Performance checks	Result
Check data storage after operation		
MCP Data	1) Ballasting/De-ballasting/Navigation operation data 2) Alarm list 3) Operation state of instruments	
LCP Data	1) Ballasting/De-ballasting/Navigation operation data 2) Alarm list 3) Operation state of instruments	
Other control device test	1) Check the capacity size of a memory card 2) Test to print the storage data transfer to USB memory card at field PC	
Remark (Describe, if the inadequate state exists, except inspection items)		

2.4.7. Safety program and training

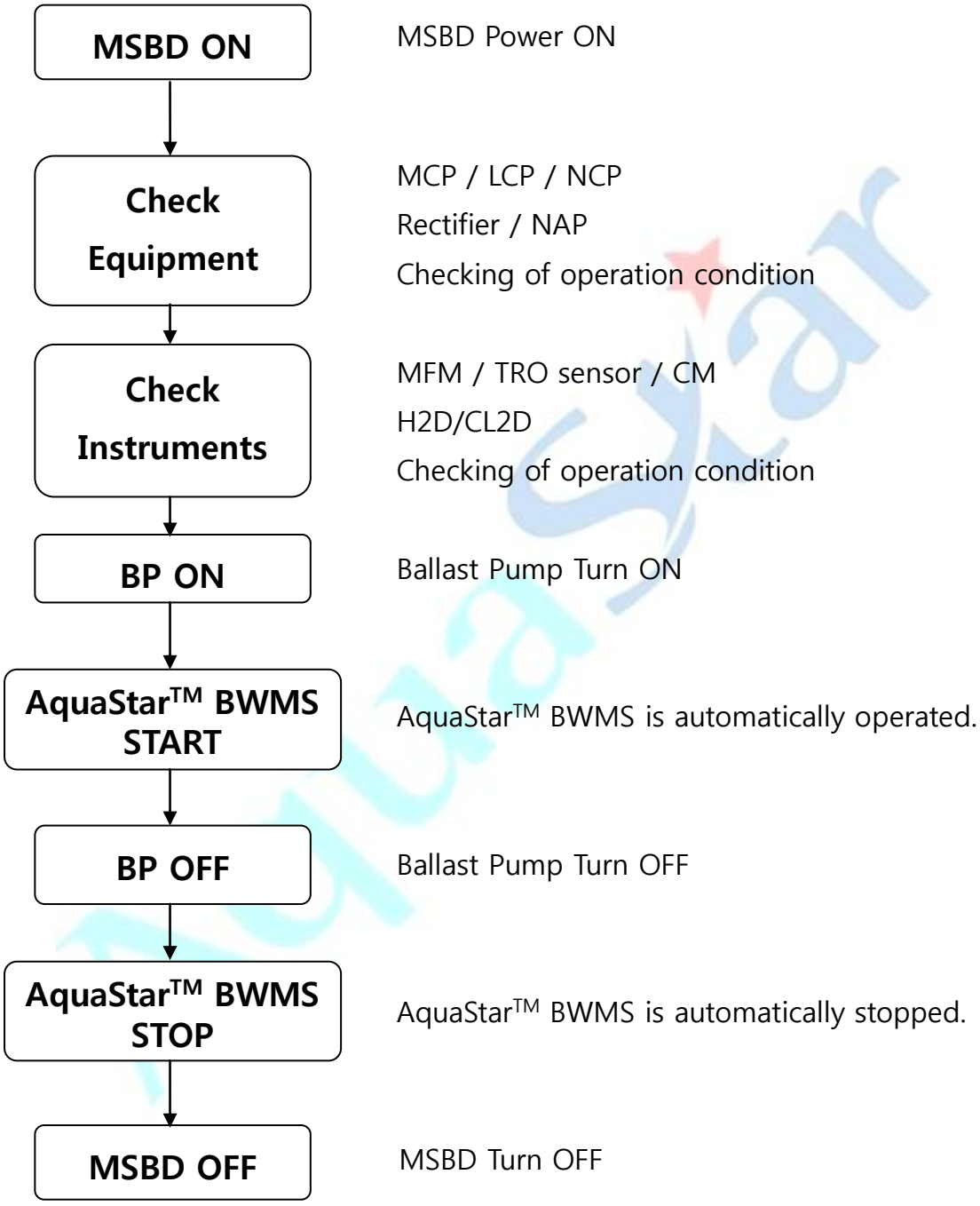
Check point	Result
1) Check to review a documented safety policy for the operator	
2) Check to understand a documented safety policy for the operator	
3) Check to establish the accident report/investigation system	
4) Check the emergency measures (Alarm) or emergency plan	
5) Check to establish the general safety program	
6) Check the reading approach for following documents - Operation manual - Emergency manual - MSDS for materials (Hazard)	
Remark (Describe, if the inadequate state exists, except inspection items)	

2.4.8. Personnel safety

Check point	Result
1) Check the operation ability (skill) for an operator - Normal operation of ballasting/de-ballasting - Emergency operation	
2) Check to wear and store the protective device - Safety shoes, safety helmet and safety gloves etc.	
3) Check the maintenance approach for an operator	
4) Check the emergency exit	
5) Check arrangement and operation for safety equipment	
Remark (Describe, if the inadequate state exists, except inspection items)	

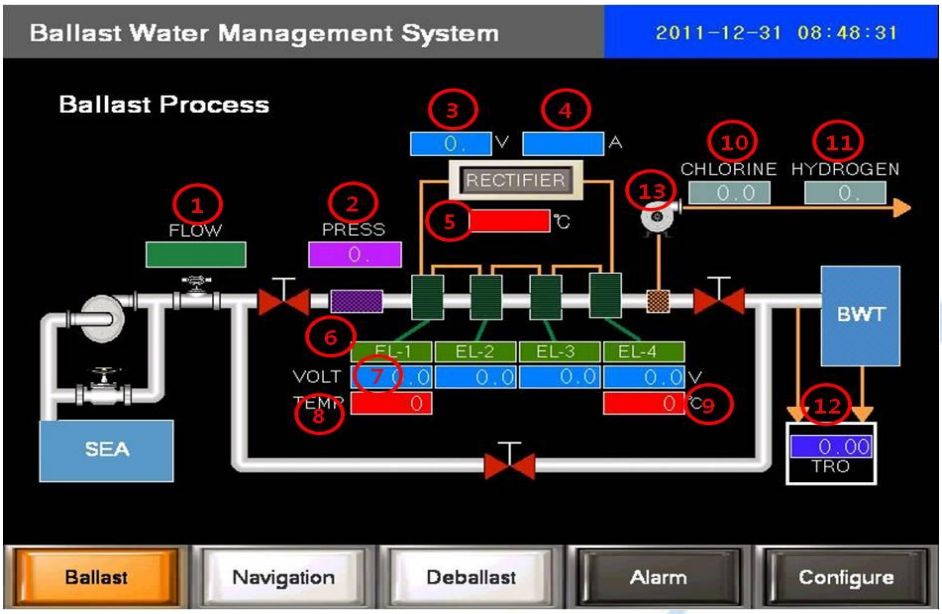
2.5. Operation Procedure

2.5.1. General

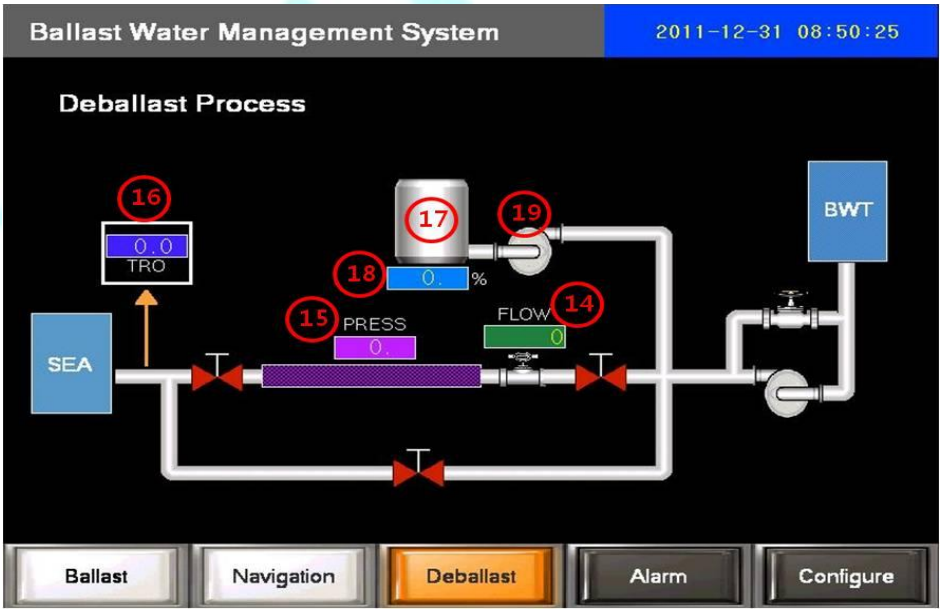


MCP/LCP display of AquaStar™ BWMS

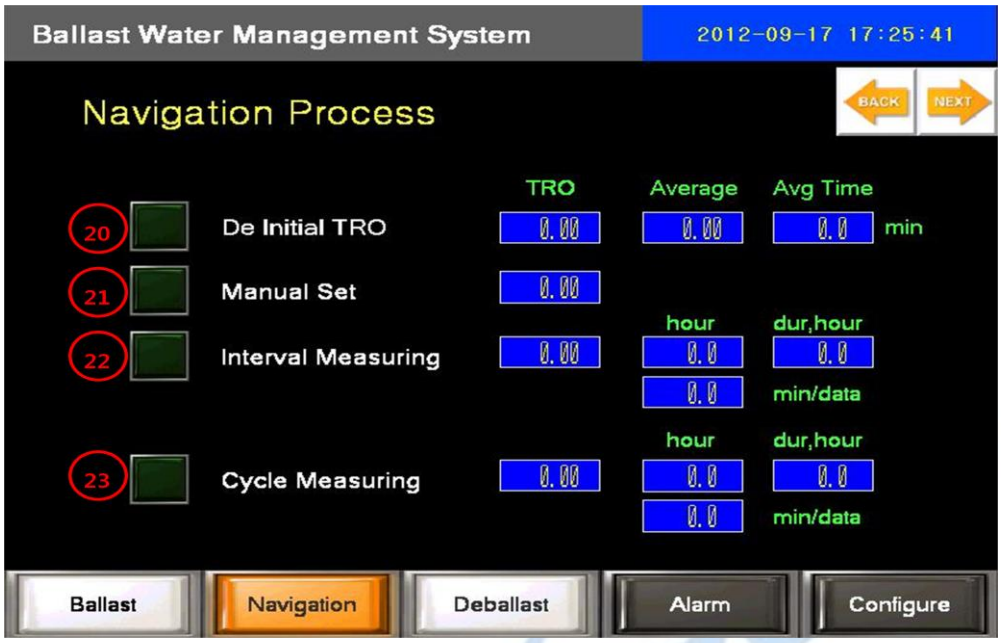
A: Ballasting process



B: De-ballasting process



C: Navigation process



Number	Equipment	Unit	Description
A	**Ballasting process status**		
1	MFM	m^3/hr	Ballasting flow rate
2	SP	kg/cm^2	SP pressure
3	Rectifier	V	Rectifier voltage
4	Rectifier	A	Rectifier ampere
5	Rectifier	℃	Rectifier temperature
6	EL	EA	Name of EL
7	EL	V	Individual EL voltage
8	EL	℃	Cathode cable temperature
9	EL	℃	Anode cable temperature
10	CL2D	mg/L (ppm)	Chlorine gas concentration
11	H2D	%	Hydrogen gas concentration
12	TRO sensor	mg/L (ppm)	Ballasting TRO concentration
13	AB		AB On/Off status

B	**De-ballasting process status**		
14	MFM	m^3/hr	De-ballasting flow rate
15	NU	kg/cm^2	NU pressure
16	TRO sensor	mg/L (ppm)	De-ballasting TRO concentration
17	NT		NT status
18	NT level	%	NT level status
19	NAP		NAP On/Off
C	**Navigation process status**		
20	TRO sensor	mg/L (ppm)	Average measuring TRO value
21	TRO sensor	mg/L (ppm)	Manual measured TRO value
22	TRO sensor	mg/L (ppm)	Interval measuring TRO value
23	TRO sensor	mg/L (ppm)	Cycle measuring TRO value

2.5.2. Preparation for operation

1) Preparation of neutralizing agent (Sodium thiosulfate)

※ The $Na_2S_2O_3$ in the actual neutralization process is used as $Na_2S_2O_3 \cdot 5H_2O$ (248g/mol).

Please put on the protective clothing, gloves, masks and goggles when you prepare the neutralizing agent solution.




※ The concentration of a neutralizing agent is 1 M (mole/L).

① Put 248 kg of a neutralizing agent into 1st NT.

② Fill with 1,000 L of fresh water into 1st NT.

③ Check the level of 1st NT.

④ Operate the air bubbling system installed 1st NT to solve a neutralizing agent.

⑤ Operate NTP installed 1st NT to move a neutralizing agent of a solution type into 2nd NT.

Operate the air bubbling system again if a neutralizing agent is not dissolved completely due to the surrounding environment.

A neutralizing agent storage: Keep in a tightly closed container, stored in a cool less than 38°C, dry, ventilated area. Protect against physical damage. Isolate from incompatible substances.

2) Preparation of TRO sensor reagent

There are two reagents required, for the instrument to operate; the buffer and the indicator. The reagents are provided "wet" and the buffer is ready to use and will last up to one year.

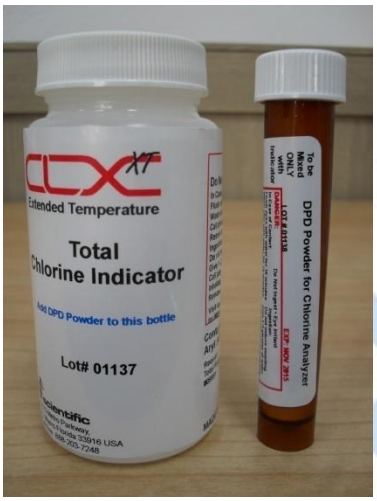
Left: indicator reagent (with DPD powder), Right: buffer solution

The smaller indicator reagent does require the addition of the DPD power to activate it.

Use caution while preparing. These reagents are caustic and can burn skin and stain clothing. The use of protective gloves, clothing and eye protection is highly recommended.

3) Preparation of indicator reagent

① Remove the cap of the small liquid indicator reagent.
② Add the contents of the DPD powder bottle (small brown bottle).
③ Cover the cap and shake to fully dissolve the powder.



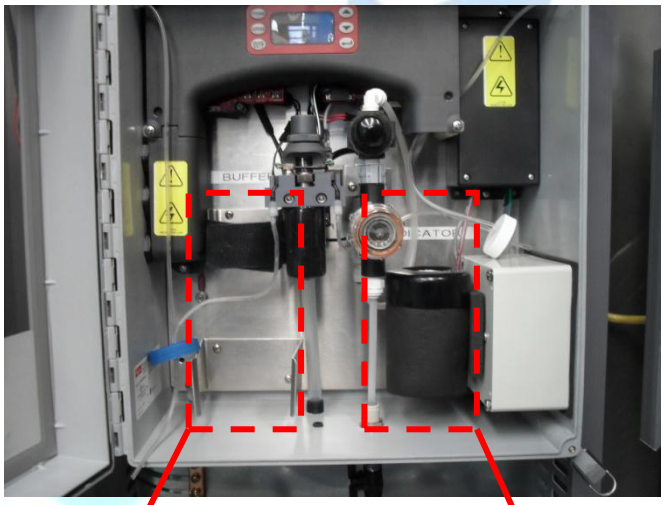
Once mixed the indicator has an expected life of 90 days if kept in the powered cooling chamber. Write the mixing date on the reagent bottle labels in the area provided. Dispose of expired reagents correctly.

4) Installation of reagents in TRO sensor

① To replace the reagents, press the "SERVICE" button; this will empty the cuvette and stop any flow of water.

② Remove the cap on both bottles replace with the cap supplied with TRO sensor. The buffer is installed on the left and the indicator is installed in the cooling chamber. The suction tube for both reagents will reach the bottom of the bottles.

③ To complete the replacement procedure, press the "PRIME" button and then the ↵ button. This will draw enough of each reagent to completely prime the tubes and replace any old solution. The system will automatically return to normal operation after it has primed.



Buffer solution Indicator reagent (added DPD powder)

Use caution when changing the reagents as they are caustic. These reagents will stain clothing and anything they contact. After changing the reagents, operators should wash their hands.

2.5.3. Operation method of AquaStar™ BWMS

2.5.3.1. Automatic (Normal) ballasting operation

Start-up procedure

1) Turn on MSBD power
2) Check the state of system
   : MCP, LCP and rectifier power on
   : Auto position in manual/auto selector switch of MCP
   : Remote position in selector switch of LCP and rectifier
3) Check the state of valve
   : Main valves open and by-pass valve close
4) Check the target TRO concentration including setting values
5) Turn on BP
6) Automatically start ballasting operation
7) Check the operating condition

Stop procedure

1) Turn off BP
2) Automatically stop ballasting operation
3) Turn off MSBD power
4) Check MCP, LCP and rectifier off

2.5.3.2. Automatic (Normal) de-ballasting operation

Start-up procedure

1) Turn on MSBD power
2) Check the state of system
   : MCP, LCP and NCP power on
   : Auto position in manual/auto selector switch of MCP
   : Remote position in selector switch of LCP, NCP and NAP
3) Check the state of valve
   : Main valve close and by-pass valve open
4) Check the target TRO concentration including setting values
5) Push de-ballast process button/lamp (Pre-operation: NAP on state)
6) After 3 minutes, turn on BP
7) Automatically start de-ballasting operation
8) Check the operating condition

Stop procedure

1) Turn off BP
2) Automatically stop de-ballasting operation
3) Turn off MSBD power
4) Check MCP, LCP, NCP and NAP off

2.5.4. Alarm and Interlock setting for system

Unit	Alarm	Interlock	Remark
MFM			
1) Ballasting process (m^3/hr)	10~110%	5~115%	
2) De-ballasting process (m^3/hr)	10~110%	5~115%	
SP			
1) PI	X	X	
2) PT (kg/cm^2)	over 5	over 7	
Electrolyzer system unit			
1) EL temp. (℃)	over 70	over 85	
2) EL voltage (V)	over 6	over 7	
3) Rectifier voltage (V)	over 24	over 28	
4) Rectifier ampere (A)	80% of Max. cap.	90% of Max. cap.	
5) Rectifier temp. (℃)	over 80	over 90	
Neutralization system unit			
1) NT level (%)	under 30	under 10	
2) Flow rate	X	0	
3) NU			
PI	X	X	
PT (kg/cm^2)	over 5	over 7	
Others			
1) CM (mS/cm)	under 10	under 5	
2) H2D (%)	over 25 of LEL	over 50 of LEL	
3) CL2D (ppm)	over 0.5	over 1	
4) TRO concentration (ppm)			
Ballasting process	under 8 / over 10 (continuously 2times)	under 8 / over 10 (continuously 3times)	
De-ballasting process	over 0.15	over 0.2	

2.6. Emergency Operation

2.6.1. Emergency switch

Emergency switch used at emergency situation is installed at MCP and LCP, respectively.
When the operator pushes the emergency switch, AquaStar™ BWMS and BP are stopped at once. After solving the emergency situation, AquaStar™ BWMS should be restarted.

If an emergency occurs, please contact directly AQUA Eng. Co., Ltd.

Operation condition of emergency switch

① In case of, exist the risk of ship and crew
② In case of, abnormal operation of MCP, LCP, rectifier and BP etc.
③ In case of, do not work Interlock of MCP
④ In case of, the alarm operation of LCP/MCP or do not search for the long time cause
⑤ In case of, generate the errors H2D/CL2D or do not work H2D/CL2D
⑥ In case of, the gas leakage or water leak generate
⑦ In case of, need to quickly stop AquaStar™ BWMS by diverse risk of ship
⑧ In case of, fire and short circuit generate
⑨ In case of, TRO is abnormally high and low
⑩ In case of, the pressure of SP rapidly increase
⑪ In case of, the pressure of NU rapidly increase

Location of emergency switch

MCP emergency switch

LCP emergency switch

Check item during emergency switch

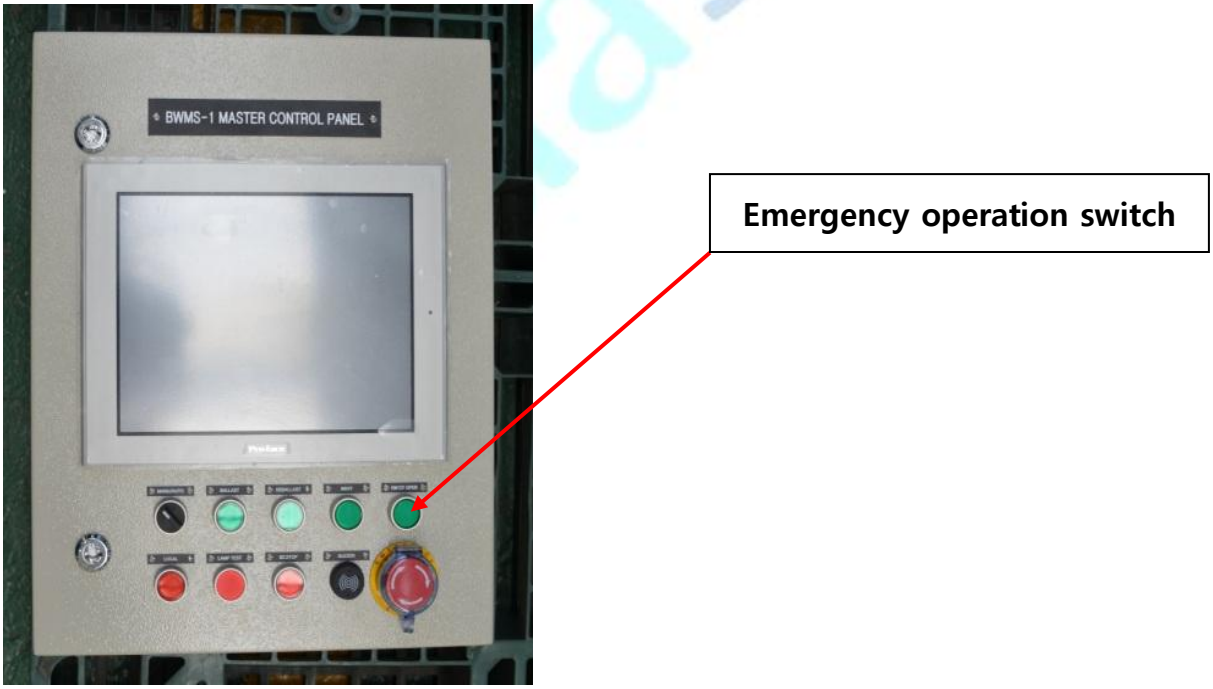
① Check the operation condition of H2D/CL2D
② Check the rectifier power off
③ Check the pressure of SP
④ Check the pressure of NU
⑤ Check the power off of NAP
⑥ Check the operation condition of TRO sensor
⑦ Check the power on of MCP and LCP
⑧ Check BP off

2.6.2. Emergency operation switch

AquaStar™ BWMS is designed to conduct the ballasting operation or de-ballasting operation at the same time with BP working. When the operator pushes the emergency operation switch, the operation of BP will be continued but the operation of AquaStar™ BWMS will be stopped. At this time, the data related to emergency state is stored.

Before emergency operation switch uses, please contact directly AQUA Eng. Co., Ltd.

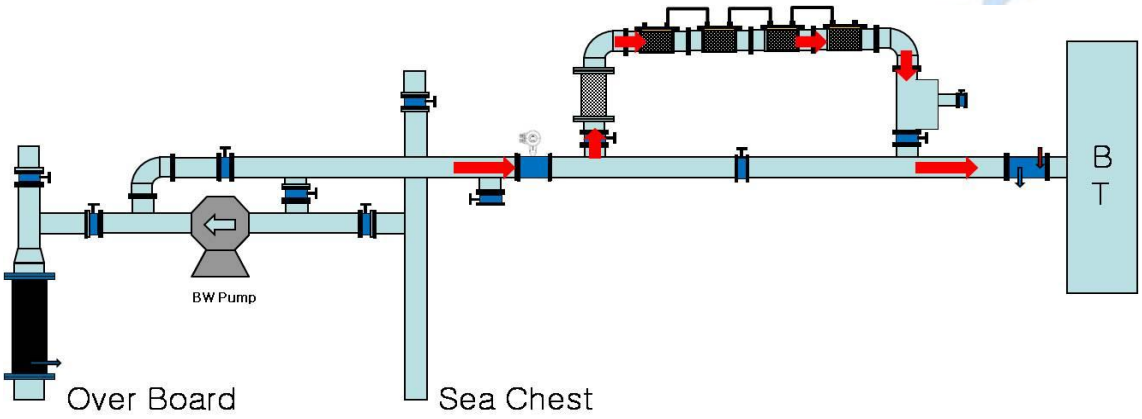
AQUA Eng. Co., Ltd. is not liable for any troubles caused by using of emergency operation switch without the approval of AQUA Eng. Co., Ltd.



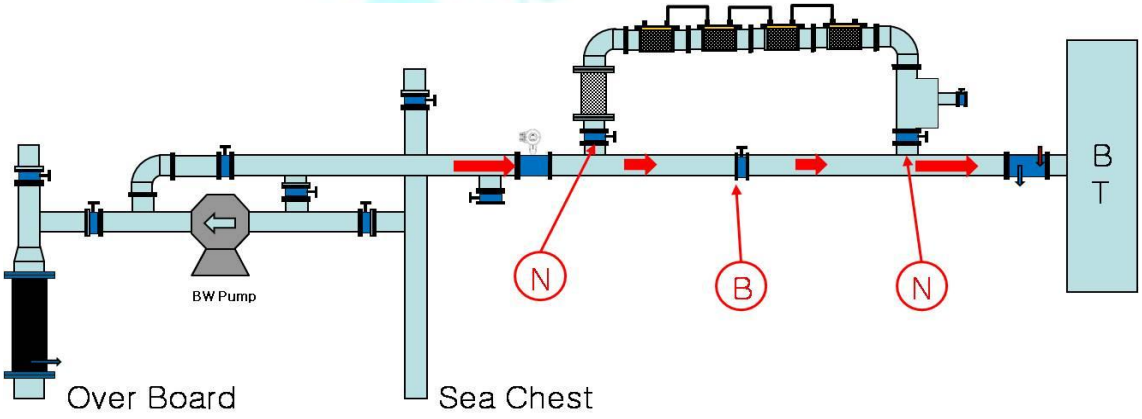
2.6.3. By-pass operation

Please, use only in case of by-pass operation should be needed. By-pass operation activates an alarm and the event can be stored and displayed. The operator must record the information for by-pass operation.

Flow diagram of normal operation



Flow diagram of abnormal operation



1) Valve-N close : Normal operation valve
2) Valve-B open : By-pass valve

3. Application of AMS and US Type Approval

3.1. Authority information for foreign Type Approval

Model	Treatment rated capacity (m^3/hr)
AquaStar™ BWMS H-200	200
AquaStar™ BWMS H-200S/H-200S-Ex[1]	350
AquaStar™ BWMS H-250	500
AquaStar™ BWMS H-300/H-300-Ex	800
AquaStar™ BWMS H-350/H-350-Ex	1,100
AquaStar™ BWMS H-450	1,800
AquaStar™ BWMS H-550	2,600
AquaStar™ BWMS H-650/H-650-Ex	3,000
AquaStar™ BWMS H-700	4,000
AquaStar™ BWMS H-750	5,000

[1] Explosion-proof type

- 14 models (10 standard models and 4 Explosion-proof models)
- Type Approval Certificate of BWMS from Republic of Korea
- Refer to Appendix A (Type Approval certificate for BWMS) for Type Approval Certificate of AquaStar™ BWMS.

Foreign Type Approval	MLTM / Republic of Korea
Address	#88, Gwanmun-ro, Gwacheon-si, Gyeonggi-do, Korea
Phone number	+82-44-201-4108
Name (Point of contact)	Hae Kwang, Kim
Email	miraepa7@mltm.go.kr

3.2. Evaluation of existing data and Type Approval requirements

In accordance with 33 CFR Part 151 / 46 CFR Part 162 of "Standards for Living Organisms in Ship's Ballast Water Discharged in U.S. Waters", data or information included the application for USCG AMS determination and US Type Approval are attached to appendices (Appendix A ~ I) of this document.

3.3. AMS review checklist

Alternate Management System Review Checklist			
A **Guideline (G8) Specification** **(G8 section noted in brackets)**	**B** **Cross Reference** **(Applicant to identify page, paragraph and/or table where this information is located)**	**C** **Adequacy** **(USCG to note Y/N/NA)**	**D** **Comments** **(Applicant-black; USCG-red)**
1. BWMS documentation [5]			
1.1 BWMS description, including diagrammatic drawing(s) showing typical pumping and piping arrangements (including a Bill of Materials and the specifications and standard/s which it meets), sampling facilities for control and monitoring systems, operational outlets for treated water and waste streams [5.1]	Chapter 2 (8~95 pages) of this document and Appendix B (Drawing Package)		
1.1.1 Control equipment automatically monitors and adjusts necessary treatment dosages, intensities or other aspects of the BWMS necessary for proper administration of necessary treatment [4.10]	Chapter 2.2 (16~33 pages) of this document and Appendix C-2 (Operation program user's manual)		
1.1.2 Control equipment incorporates a continuous self-monitoring function when BWMS is in operation [4.11]	Chapter 2.2 (16~33 pages) of this document and Appendix C-2 (Operation program user's manual)		
1.1.3 Monitoring equipment record the proper functioning or failure of the BWMS [4.12]	Chapter 2.2 (16~33 pages) of this document and Appendix C-2 (Operation program user's manual)		
1.1.4 Control equipment stores data on monitored functions and conditions	Chapter 2.2 (16~33 pages) of this		

for at least 24 months; stored data can be displayed or printed for inspection [4.13]	document and Appendix C-2 (Operation program user's manual)		
1.2 Protections against interference [4.5]			
1.2.1 Every access beyond requirements of 4.4 requires breaking a seal [4.5.1]	Chapter 2.3.1 (34 page) of this document		
1.2.2 Visual alarm is activated whenever the BWMS is in operation for purpose of cleaning, calibration, or repair; such events recorded by control equipment [4.5.2]	Chapter 2.2.5 (32~33 pages) of this document and Appendix C-2 (Operation program user's manual)		
1.2.3 Suitable emergency over-rides/by-passes to protect ship and crew [4.5.3]	Chapter 2.6 (92~95 pages) of this document		
1.2.4 By-passes activate an alarm and the event is recorded by the control equipment [4.5.4]	Chapter 2.6 (92~95 pages) of this document		
1.3 Audible and visual alarm signals in stations from which ballast water operations and ballast water management are controlled [4.3]	Chapter 2.2.5 (32~33 pages) of this document and Appendix C-2 (Operation program user's manual)		
1.4 Manufacture's equipment manuals containing details of major components of the BWMS and their operation and maintenance [5.1.2]	Chapter 2.3 (34~56 pages) of this document and Chapter 2 (23~61 pages), 3 (62~90 pages) and 6 (111~122 pages) of Appendix C-1 (Operation Manual)		
1.5 Operation and technical manual for complete BWMS covering arrangements, operation, and maintenance of the BWMS as a whole, and specifically describing any parts not covered by manufacturers equipment manuals [5.1.3]	Chapter 2.3 (34~56 pages) of this document and Chapter 2 (23~61 pages), 3 (62~90 pages) and 6 (111~122 pages) of Appendix C-1 (Operation Manual)		
1.5.1 Operations section of the manual includes normal operational procedures [5.1.4]	Chapter 2.5 (81~91 pages) of this document and Chapter 3 (62~90		

	pages) of Appendix C-1 (Operation Manual)		
1.5.2 Documentation of simple and effective means for operation and control [4.8]	Chapter 2.5 (81~91 pages) of this document and Chapter 3 (62~90 pages) of Appendix C-1 (Operation Manual)		
1.5.3 Operations manual includes procedures in the event of a malfunction of the BWMS, including emergency actions necessary for securing the ship [5.1.4]	Chapter 2.6 (92~95 pages) of this document and Chapter 4 (91~96 pages) of Appendix C-1 (Operation Manual)		
1.5.4 Operations manual contains maintenance procedures [5.1.3]	Chapter 6 (111~122 pages) of Appendix C-1 (Operation Manual)		
1.6 All working parts of the BWMS liable to wear or damage easily accessible for maintenance [4.4]	Appendix C-4 (Drawing for maintenance of BWMS) and Chapter 6 (111~122 pages) of Appendix C-1 (Operation Manual)		
1.6.1 Means provided to check in drift of, repeatability by, measuring devices that are part of control equipment, and for re-zeroing control equipment meters [4.14]	Appendix H (Calibration Procedure)		
1.6.2 Facilities incorporated for checking the performance/calibration of components of BWMS that take measurements [4.6]	Appendix H (Calibration Procedure)		
1.7 Operations manual describes methods for conditioning of treated water prior to discharge to control residual treatment chemicals, disinfection by products, and the general suitability of the treated water for discharge [5.1.5]	Chapter 2.2 (16~33 pages) and chapter 2.5.3.2 (90 page) of this document		
1.8 Technical section of the manual includes adequate information (including description and diagrammatic drawings of monitoring and	Chapter 2.4.1, 2.4.2 and 2.4.3 (57~70 pages) of this document		

electrical/electronic wiring) to enable faultfinding [5.1.7]			
1.9 Technical section of the manual includes specifications defining, *inter alia*, requirements for location and mounting of components, arrangements for sampling by control and monitoring equipment, and arrangements for ensuring safe operation [5.1.8]	Chapter 2.3.6 (52~56 pages) of this document		
1.9.1 BWMS components, if intended for fitting in locations where flammable atmospheres may be present, comply with relevant safety regulations; certified by Administration as safe for use in a hazardous area [4.9]	Chapter 2.2.5 (32 page) of this document and Appendix A (Type Approval certificate for BWMS)		
1.10 Operations and technical manual contains a recommended test and checkout procedure, specifying all the checks to be carried out in a functional test following installation and a test by a surveyor when carrying out an onboard survey to confirm the installation meets the manufacturer's specific installation criteria [5.1.9]	Chapter 2.4 (57~80 pages) of this document		
1.11 BWMS is robust and suitable for working in the shipboard environment, with design, construction and materials, including electronic and electrical components (including a Bill of Materials and the specifications and standard/s which it meets), adequate for intended service [4.7.1]	Appendix B (Drawing Package) and Appendix E-1, E-2 and E-3 (Certificate of Environmental test_H-300, H-650 and sensors)		
2. Type approval certificate			
2.1 Type approval certificate issued by, or on behalf of, the Administration [6.1]	Appendix A (Type Approval certificate for BWMS)		
2.1.1 Specification of any limiting conditions on the usage of the BWMS, including but not limited to ballast water volumes, flow rates, salinity, temperature, etc. [6.1 and 6.2]	Appendix A (Type Approval certificate for BWMS) and Appendix G-1 (19th GESAMP)		
2.1.2 Specification of the type and model of the BWMS, including identification of duly dated equipment assembly drawings bearing model specification numbers or equivalent identification details [6.5]	Appendix A (Type Approval certificate for BWMS)		

3. Environmental and public health impacts assessment documentation			
3.1 Protections reduce to minimum danger to persons (i.e., hot surfaces, moving parts, exposure to chemicals, UV, etc) [4.7]	Appendix G-2 (Application for Basic Approval) and G-3 (Application for Final Approval)		
3.2 Complete application dossiers for IMO active substance basic and final approvals [Annex part 1, 1.6.4]	Appendix G-2 (Application for Basic Approval) and G-3 (Application for Final Approval)		
3.3 Adequate arrangements for storage, application, mitigation, and safe handling of any substances of a dangerous nature [4.2]	Appendix G-2 (Application for Basic Approval) and G-3 (Application for Final Approval)		
4. Quality Assurance (QA) and Quality Control (QC) [Annex Part 1, 2.1]			
4.1 Quality Management Plan (QMP) addressing the quality control management structure and policies of the testing body, including all subcontractors and outside laboratories [Annex Part 2, 2.1.2.2]	Appendix I (QMP and QAPP for tests)		
4.2 Quality Assurance Project Plan (QAPP) describing the specifies of the BWMS, the test facility, and other conditions affecting the design and implementation of the test procedures [Annex Part 2, 2.1.2.3]	Appendix I (QMP and QAPP for tests)		
4.3 Shipboard Test Plan and Report [Annex Part 2, 2.2.2.1]	Appendix F-1 (Certificate of Shipboard test)		
4.3.1 Documentation that treatment rated capacity of BWMS was appropriate for ship [Annex Part 2, 2.2.2.2]	Appendix F-3 (Operation data)		
4.3.2 Documentation that the volume and pumping rate of ballast water during test was consistent with normal ballast operations of ship [Annex Part 2, 2.2.2.3]	Appendix F-3 (Operation data)		
4.3.3 Documentation of all test cycles, demonstrating three valid consecutive test cycles showing discharge of treated ballast water meeting regulation	Chapter 1.7 (7~8 pages) of Appendix F-1 (Certificate of Shipboard test)		

D-2 standard [Annex Part 2, 2.2.2.4 and 2.2.2.8]			
4.3.4 Tests meet minimum organism concentrations during uptake of more than 10 times the maximum permitted values in regulation D-2.1 [Annex Part 2, 2.2.2.5]	Chapter 1.7 (7~8 pages) of Appendix F-1 (Certificate of Shipboard test)		
4.3.5 Documentation that sampling regime was appropriate, either by meeting G8 recommendations for control and treated ballast water including: 1) Control tank replicates; 2) Treatment tank replicates 3) Sample sizes; or 4) By documenting appropriate validation of sample volumes and numbers, per EPA ETV [Annex Part 2, 2.2.2.6]	Chapter 1.5 (6 page) of Appendix F-1 (Certificate of Shipboard test)		
4.3.6 Documentation that test cycles completed over at least six months [Annex Part 2, 2.2.2.7]	Chapter 1.6 (6 page) of Appendix F-1 (Certificate of Shipboard test)		
4.3.7 Documentation of source water characterization for salinity, temperature, POC and TSS [Annex Part 2, 2.2.2.9]	ATTACHMENT Ⅲ (11~16 pages) of Appendix F-1 (Certificate of Shipboard test)		
4.3.8 Documentation of system operations, including: 1) Volume and locations of uptake & discharge volume; 2) Possible reasons for unsuccessful test cycle or failure of a cycle to meet D-2 standard; 3) Scheduled maintenance 4) Unscheduled maintenance and repair 5) Appropriate engineering parameters; and 6) Proper functioning of control & monitoring equipment [Annex Part 2, 2.2.2.10]	1): Appendix F-2 (Volume and location of uptake & discharge) 2): N/A (Not Applicable) 3): Appendix F-4 (Check list of maintenance) 4): N/A (Not Applicable) 5): Appendix F-3 (Operation data) 6): Appendix C-2 (Operation program user's manual)		

4.4 Land-based Test Plan and Report [Annex Part 2, 2.4]	Appendix D-1 (Certificate of Land-based test)		
4.4.1 Description of test set-up, including: 1) Arrangement of BWMS [Annex Part 2, 2.3.9] 2) Piping and pumping arrangements [Annex Part 2, 2.3.9] 3) Tank specifications (treatment and control) [Annex Part 2, 2.3.10] 4) Facilities for representative sampling [Annex Part 2, 2.3.12] 5) Augmentation facilities for DOC, POC, TSS and standard test organisms if used [Annex Part 2, 2.3.12]; and 6) Monitoring facilities for environmental parameters including pH, temperature, salinity, dissolved oxygen, TSS, DOC, POC and turbidity [Annex Part 2, 2.3.12]	1): Appendix D-2 (P&ID) 2): Appendix D-2 (P&ID) 3): Appendix D-3 (Tank specifications) 4): Appendix D-4 (Sampling port) 5): Appendix D-6 (Augmentation facility) 6): Appendix D-4 (Sampling port) and chapter 1.1 ~ 1.7 (5~10 pages) of Appendix D-1 (Certificate of Land-based test)		
4.4.2 Documentation system was operated at treatment rated capacity, or scaled as follow: 1) 200 M3/hr<TRC<1,000 M3/hr – downscaled no more than 1:5; 2) TRC > 1,000 M3/hr – downscaled no more than 1:100; and 3) Documentation of mathematical modeling and/or calculations demonstrating downscaling used would not affect functioning and effectiveness onboard ship at full scale for which certification is intended [Annex Part 2, 2.3.13]	Appendix D-5 (Operation data)		
4.4.3 Description of cleaning procedures for test set-up before starting testing, and between test cycles [Annex Part 2, 2.3.11]	Appendix D-7 (Washing check list)		
4.4.4 Description of sampling and analysis procedures for organisms and environmental/water quality parameters, including: 1) Identification of standard methods [Annex Part 2, 4.2] 2) Validation of non-standard methods [Annex Part 2, 4.3]	1), 2) and 3): Appendix I-1 (QMP and QAPP of Land-based test) 4): Appendix D-4 (Sampling port) and Appendix D-6 (Augmentation		

3) Validation of appropriateness of sample processing times [Annex Part 2, 2.3.34]; and 4) Description and validation of facilities and procedures for collecting representative samples [Annex Part 2, 2.3.31; 2.3.32; 2.2.23; 2.3.28]	facility)		
4.4.5 Results of all analyses for organisms, challenge conditions and BWMS performance indicators [Annex Part 2, 2.3.23; 2.3.25]	Chapter 1.7 (8~10 pages) of Appendix D-1 (Certificate of Land-based test)		
4.4.6 Documentation the BWMS was operated and performed as designed within its specified parameters including power consumption, flow rate, etc. [Annex Part 2, 2.3.4; 2.3.24]	Appendix D-5 (Operation data)		
4.4.7 Documentation of all test cycles, demonstrating 5 valid tests with treated water meeting the D-2 discharge standard for each salinity regime for which testing was conducted [Annex Part 2, 2.3.1; 2.3.17; 2.3.18; 2.3.19; 2.3.20; 2.3.36]	Chapter 1.7 (8~10 pages) of Appendix D-1 (Certificate of Land-based test)		
4.5 Environmental Testing [Annex Part 3]			
4.5.1. Documentation of vibration tests [Annex Part 3, 3.4-3.7]	Appendix E-1, E-2 and E-3 (Certificate of Environmental test_H-300, H-650 and sensors)		
4.5.2 Documentation of temperature tests [Annex Part 3, 3.8-3.10]	Appendix E-1, E-2 and E-3 (Certificate of Environmental test_H-300, H-650 and sensors)		
4.5.3 Documentation of humidity tests [Annex Part 3, 3.11]	Appendix E-1, E-2 and E-3 (Certificate of Environmental test_H-300, H-650 and sensors)		
4.5.4 Documentation of heavy seas protection tests [Annex Part 3, 3.12]	Appendix E-1, E-2 and E-3 (Certificate of Environmental test_H-300, H-650 and sensors)		

4.5.5 Documentation of power supply fluctuation tests [Annex Part 3, 3.13]	Appendix E-1, E-2 and E-3 (Certificate of Environmental test_H-300, H-650 and sensors)		
4.5.6 Documentation of inclination tests [Annex Part 3, 3.14]	Appendix E-1, E-2 and E-3 (Certificate of Environmental test_H-300, H-650 and sensors)		